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BULLETIN
OF
ENTOMOLOGICAL RESEARCH.

ISSUED BY THE IMPERIAL
INSTITUTE OF ENTOMOLOGY.

EDITOR : THE DIRECTOR.

VOL. 26.

LONDON :
THE IMPERIAL INSTITUTE OF ENTOMOLOGY,
41, QUEEN'S GATE, S.W.7.

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MISCELLANEOUS.

Collections received	123, 279, 419, 587
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ERRATA.

- Page 130, 9 lines from end, for "west" read "east"
- „ 135, line 30, for "*C. quasiunivittatus*" read "*A. quasiunivittatus*"
- „ 140, line 30, for "1925" read "1923"
- „ 238, line 28, for "*Lygyrus*" read "*Ligyryus*"
- „ 326, line 3 of footnote, for "L. G. Howard" read "L. O. Howard"
- „ 333, last line, for "reared from larvae" read "reared from larvae in stalks of *Spartina brasiliensis* (J. G. Myers). Holotype ♂ and allotype ♀ from the Georgetown series."
- „ 391, 7 lines from end, for "How." read "Cam."
- „ 408, 4 lines from end, for "Ratz." read "Retz."

DATES OF PUBLICATION IN PARTS.

Part I	pp. 1-126	...	27 March 1935.
Part II	pp. 127-282	...	21 June 1935.
Part III	pp. 283-422	...	27 September 1935.
Part IV	pp. 423-590	...	16 December 1935.

IMPERIAL INSTITUTE OF ENTOMOLOGY.

BULLETIN

OF

ENTOMOLOGICAL RESEARCH.

VOL. 26.

1935.

THE CAMPAIGN AGAINST *ASPIDIOTUS DESTRUCTOR*, SIGN., IN FIJI.

By T. H. C. TAYLOR

(with three sections by R. W. PAINE).

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I. INTRODUCTION.

Aspidiotus destructor is a well-known pest of several tropical crops, mainly coconuts and bananas, and is present in most tropical countries. In Fiji it was a serious menace to the copra industry, and attempts to control it by biological means were made in 1920, when parasites were introduced from Tahiti; in 1927, when other parasites were introduced from Java; and in 1928, when predators were imported from Trinidad. The introductions made in 1920 and 1927 proved of no economic value, but the predators from Trinidad completely suppressed the pest in 1928 and 1929, and have controlled it most satisfactorily ever since.

In the course of this work a large amount of information on the habits and early stages of many different species of parasites and predators was obtained, and much useful experience in biological control was gained. The relative value of parasites and predators as agents for the control of Coccids is very improperly understood; and it is hoped that the present report, which is a full account of the Fiji campaign against this pest and deals with those insects which proved useless as well as those which were ultimately successful, may help towards a more thorough understanding of problems of this nature and prevent waste of time and money on useless introductions by other countries in the future.

In this report the species *A. destructor* is regarded as including a very closely allied form which has been described from various countries and various host-plants as *A. transparens*. There is, however, a great variety of intermediate forms between *A. destructor* and *A. transparens*. On the evidence at present available, the writer is not prepared to admit the existence of two distinct species, and prefers for the present purpose to include all these forms together as *A. destructor*.

It was at the instigation of Dr. J. D. Tothill, then Director of Agriculture in Fiji, that the writer investigated some of the natural enemies of *A. destructor* in Java and later in Trinidad, and to Dr. Tothill's administrative efforts much of the success of the campaign is due. The work was ordered and financed by the Coconut Committee, of which Dr. Tothill was the Chairman, and it received untiring support from Sir Maynard Hedstrom and Mr. E. Duncan, both members of that committee.

While the search for natural enemies was being conducted in Java and Trinidad, a study of the pest and its natural enemies in Fiji was made, in conjunction with other work, by Mr. R. W. Paine, who later undertook the work of controlling it in the island of Taveuni, where a severe outbreak occurred after satisfactory control had been established in all the other islands. The writer is most grateful to Mr. Paine for giving him full use of his notes and for writing by request several sections for this report; for these sections acknowledgment of his authorship is made in the text.

The writer is particularly indebted to Sir Geoffrey Evans, C.I.E., Principal of the Imperial College of Agriculture, Trinidad, for much hospitality and assistance. The advice and help of Professor Ballou and Mr. Ulrich, also of the Imperial College, were greatly appreciated also. In Java, the writer received every possible facility for this work at the Institute for Plant Diseases, Buitenzorg, and is greatly indebted to Dr. S. Leefmans, Director of the Institute, and his staff, for their kindness on this as on several other occasions.

II. LIFE-HISTORY AND LIFE-CYCLE OF *ASPIDIOTUS DESTRUCTOR*.

Aspidiotus destructor is a Diaspine Coccid. It is covered by a flat, whitish, waxy scale, of extremely delicate texture and very flexible, which, when seen under the microscope, resembles the thinnest tissue paper. The scale is semi-transparent, so that the colour and outline of the insect are visible through it. Fully-developed female scales are nearly circular in outline, and males are oval. At each moult of the female insect the dorsal skin becomes incorporated in the scale, and the cast skins are readily visible arranged concentrically in the centre of the scale (fig. 1, a). In the male, only the first skin is incorporated in the scale.

The species is oviparous, and the eggs hatch under the scale, giving rise to active larvae which escape from the scale soon after hatching by pushing their way under the edge of it. The larvae then crawl slowly over the leaves in search of suitable places for feeding, and then affix themselves by inserting their rostra into the leaf tissues, and they never move again. The duration of this free-living period varies from 2 to 48 hours, but does not normally exceed 12 hours, and it was found that the larvae cannot survive without food for more than 48 hours approximately.

Soon after the larva has attached itself to the leaf the waxy secretion which forms the scale makes its appearance in the form of minute threads. The production of the threads is accompanied by rotation of the larva about its rostrum, and the rotation results in the matting together of the threads to form eventually a thin continuous scale, which adheres all round its periphery to the leaf and entirely covers the larva. The formation of the scale occupies about 12 hours.

Fixation of the larva is followed by a period of fairly rapid growth, which in turn is followed by a resting period preparatory to the first moult. The appendages are lost at the first moult. Until the middle of the second instar period there is no difference in appearance between the sexes, and the colour up to this stage is pale yellow in both sexes; but after this the male insect begins to become reddish and is then easily distinguished from the female, which retains its pale yellow colour. A difference in shape is noticeable too, the male becoming elliptical at about this time, while the female is roughly circular, except for the bluntly projecting pygidium. Further, towards the end of the second instar the eyes of the male become apparent as dark spots.

The subsequent development differs greatly in the two sexes. The male, which is full-grown in the second instar, becomes a pupa at the moult which terminates that instar, the pupa being of normal Coccid form. The adult, winged male emerges from the pupa and in so doing pushes the pupal and second larval skins out at the posterior end of the scale. The adult male remains motionless under the scale for two days before it finally escapes to crawl actively over the leaf and occasionally to fly.

The female, unlike the male, continues its growth after the second moult, and does not change appreciably in form. Moreover, the female reaches maturity without a third moult. Growth is rapid in the third instar, and soon after growth ceases oviposition commences. When full-grown, the female is merely a sac of eggs, greatly flattened and nearly circular. Its usual colour is yellow, but orange and greenish-yellow forms are common, the colour varying to a considerable extent with the food-plant. The skin is corrugated by the pressure of the mature eggs within it. By transmitted light, the insect is transparent, and the eggs are very clearly visible, almost completely filling the body (fig. 1, b).

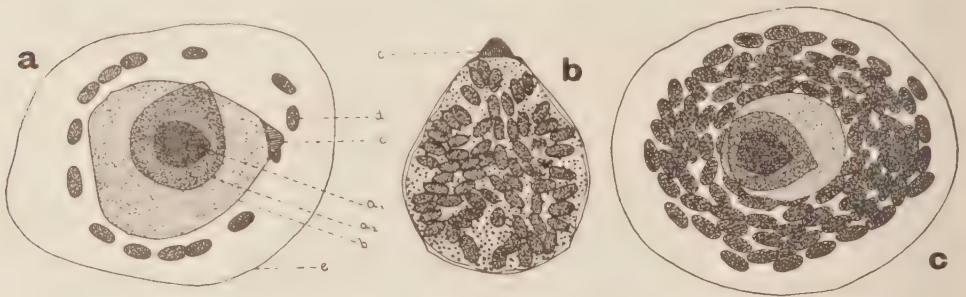


Fig. 1. Mature ♀♀ of *Aspidiotus destructor*, as seen by transmitted light (slightly diagrammatic): a, ♀ which has commenced ovipositing (eggs in body of ♀ not shown); b, the same ♀ as in a, at same time, with scale removed; c, another ♀ which has almost finished ovipositing; a₁, a₂, the two cast skins incorporated in the scale; b, the scale-insect; c, pygidium; d, egg; e, scale.

The process of oviposition occupies about 9 days. The eggs are not laid at regular intervals during this time, but are usually laid in batches of 3 or 4, in moderately quick succession, with an interval of several hours between batches. The female rotates under the scale as it oviposits, the pygidium moving round for the length of one egg after each egg is deposited. The rotation is sufficiently rapid to be readily visible, and is effected by a wave-like movement of the edge of the body, which is pressed against the scale during the process. It results at first (fig. 1, a) in the deposition of a single circle of eggs, concentric with the centre of the scale and at a distance from the centre equal to half the length of the insect. As the eggs are expelled the body shrinks, so that the second circle of eggs lies just within the first; and so on, until finally the body shrinks to a small yellow mass, in the centre of the scale, surrounded by several circles of eggs packed very closely together (fig. 1, c). The number of eggs laid by individuals on coconut in Java was found to vary from 65 to 110, with an average of 90. The eggs are almost white at first, but become yellow after a few days, and since the outer eggs are the first laid, they are yellow while those towards the centre are still white.

The eggs hatch in the order in which they were laid, and all the larvae can therefore escape easily, without obstruction. The incubation period is approximately equal to the oviposition period, with the result that the first eggs begin to hatch at approximately the time when the last ones are laid.

Males of this species are abundant, but there is no uniformity in the sex ratio of different batches. Wholly male and wholly female batches are common, and all intermediate ratios occur. The abundance of males is remarkable, because the male sex appears as a rule to be superfluous, oviposition without copulation resulting in the production of both sexes. It was frequently noticed, in both Fiji and Java, that after a succession of largely female generations a wholly male generation suddenly and unaccountably appears. This usually occurs in the case of isolated batches of scale which have probably originated from a single female, and if this is true, we must conclude that although parthenogenesis is common and general, and produces both sexes, it becomes necessary sooner or later for copulation to take place with males from an independent batch. It must, however, be borne in mind, that the nature of the food supply may have a bearing on this problem. The writer has often observed that certain parasites, when induced to oviposit in abnormal hosts or to oviposit excessively in normal hosts, produce wholly male generations for which only the food supply can be responsible.

The two tables which follow show the durations of the various stages. The data were obtained by Paine in Fiji, in May 1927, at a mean temperature of 79°F. for that month, and the host-plant was a seedling coconut.

					Max.	Min.	Mean
					Days	Days	Days
<i>Males</i> (14 individuals).							
Incubation period	...	...	...	...	8	8	8
1st instar	...	...	...	...	11	9	10
2nd instar	...	...	...	...	8	5	6½
Pupal period	...	...	...	...	6	4½	5
Adult under scale	...	...	...	...	2	1½	2
Total* (oviposition to emergence from scale)	...	...	...	...	35	30	32
					Max.	Min.	Mean
					Days	Days	Days
<i>Females</i> (4 individuals).							
Incubation period	...	...	...	...	8	8	8
1st instar	...	...	...	...	10	7	8¾
2nd instar	...	...	...	...	10	8	9½
3rd instar (pre-oviposition)	...	...	...	...	9	8	8½
Total* (oviposition to maturing female)	...	...	...	...	35	34	34½

Since oviposition proceeds for about 9 days, the total life-cycle (egg to egg) varies from 34 to 44 days, with a mean of 38½ days. This is equivalent to 9½ generations per annum.

In Java, the writer obtained accurate figures (in September 1926) for the incubation period and for the total life-cycle of females, but not for the separate instars. The incubation period was 8 days, as in Fiji. The total cycle for females covered 31 days on the average, which is appreciably less than in Fiji—presumably on account of a rather higher mean temperature. It was noted in Java that, as a general rule, males emerged a few days before the females of the same age commenced oviposition, and Paine's figures show that this applies in Fiji also.

* The figures quoted represent actual individual records and are not obtained from the figures above them.

FIJI ISLANDS.—Rough Map, showing all islands and localities referred to in text.



- | | | |
|-----------------|-----------------|--------------------|
| 1. Bua. | 16. Nabokoyia. | 31. Qacavulu. |
| 2. Bureta. | 17. Nabouwalu. | 32. Rewa River. |
| 3. Cawaci. | 18. Nabukelevu. | 33. Salt Lake. |
| 4. Daria. | 19. Nacaga. | 34. Savu-savu Bay. |
| 5. Devadara. | 20. Nacangai. | 35. Sigatoka. |
| 6. Dreketi. | 21. Nadi. | 36. Solevu. |
| 7. Garani. | 22. Nadroga. | 37. Suva. |
| 8. Korolevu. | 23. Nagasau. | 38. Vanuasou. |
| 9. Levuka. | 24. Nagigi. | 39. Vunilagi. |
| 10. Lovoni. | 25. Naidi. | 40. Vunisea. |
| 11. Mt. Vernon. | 26. Nasau. | 41. Wailevu. |
| 12. Mua. | 27. Nasese. | 42. Wainunu River. |
| 13. Muanicula. | 28. Naseva. | 43. Wairiki. |
| 14. Mudu. | 29. Nasinu. | 44. Waiyevo. |
| 15. Nabeka. | 30. Natewa Bay. | 45. Yanuca lailai. |

III. ECONOMIC IMPORTANCE OF *A. DESTRUCTOR* IN FIJI PRIOR TO 1928

(by R. W. Paine).

First Appearance in Fiji.

So far as we have been able to find out, it is not known how or exactly when *Aspidiotus destructor* first came to Fiji. Jepson⁸ does not list it as a pest of coconuts in his report of 1911. But in 1912⁹ it was doing considerable damage to bananas in the Rewa district, which indicates that it must have then been in the country for several years.

The early references to it are all on bananas, and it does not seem to have been recorded as a coconut pest until 1916.¹⁰ It would seem probable that *A. destructor* reached Fiji about the year 1905.

Host-plants.

This scale feeds on a large assortment of plants belonging to widely different families. It probably enjoys the distinction of being able to feed on a larger number of different plants than any other insect of economic importance in Fiji.

We have not seen the publication of any complete list of its food-plants in Fiji, so that we append here a list which it is hoped includes all records of new hosts, references to which have appeared from time to time in the publications of the Fiji Department of Agriculture and in the unpublished reports of plantation inspectors.

<i>Cocos nucifera</i>	Coconut
<i>Musa</i> sp.	Banana
<i>Piper methysticum</i>	"Yaqona" *
<i>Piper macgillivrayi</i> , etc.	"Yaqoyaqona," etc.
<i>Barringtonia</i> spp.	"Vutu," etc.
<i>Cassia obtusifolia</i> }	"Ka moce"
<i>Cassia occidentalis</i> }	
<i>Psidium guajava</i>	Guava
<i>Mangifera indica</i>	Mango
<i>Carica papaya</i>	Paw-paw
<i>Eugenia malaccensis</i>	"Kavika"
<i>Inocarpus edulis</i>	"Ivi"
<i>Spondias dulcis</i>	"Wi"
<i>Aleurites moluccana</i>	"Lauci"
<i>Hevea brasiliensis</i>	Para rubber
<i>Wormia biflora</i>	"Kulava"
<i>Persea gratissima</i>	Avocado pear
<i>Zingiber officinale</i>	Ginger
<i>Tetranthera vitiana</i>	"Lidi"
<i>Laportea vitiensis</i>	"Salato"
<i>Dioscorea nummularia</i>	"Tivoli"
<i>Poinsettia</i> sp.	Common garden variety.

Of this long host list the following plants only are heavily attacked:—Coconuts, bananas, species of *Piper*, species of *Barringtonia*, and paw-paw. From the economic standpoint *A. destructor* causes extensive damage in Fiji to only four groups, viz.: coconuts, bananas, "yaqona," and avocado.

In other countries, many plants not included in the foregoing list have been recorded as host-plants for this scale. These include: camphor, cocoa, manihot,

* All the names in inverted commas are Fijian.

pandanus, castor, tea, oil palm, breadfruit, and cotton. It is therefore a potential pest of a great variety of tropical crops.

Early Reports of Scale on Coconuts.

Although *Aspidiotus destructor* was first reported in Fiji as a pest on bananas, we are concerned in the present paper more particularly with the damage it has caused to the coconut crop, and propose here to give a short summary of the information contained in the reports about the "Coconut Scale" prior to the year 1927.

In 1915, although recorded as a pest on bananas, it had not been reported on coconuts. In the following year, however, it was recorded on coconuts at Rewa, though not in abundance, and it was included by Jepson in a list of pests of coconuts. In 1917, Knowles does not include it in the list of coconut pests given in his annual report. By 1920 the scale had begun to spread alarmingly on coconuts, and was causing sufficient damage to warrant an entomologist being sent abroad for controlling agencies, and the adoption of quarantine measures within the Group to prevent its spread from Vitilevu, Ovalau, and neighbouring islands on which it occurred. During the next few years it spread to other islands and continued to be a serious pest on coconuts, until by 1927 it had spread throughout most of the Group and was then the most serious coconut pest in Fiji.

Factors responsible for Spread.

The spread of scale most usually takes place in one of the following three ways:—

Firstly: portions of scale-infested plants may be carried by human agency. It would seem probable that the spread of scale from island to island has been brought about principally by this means. Baskets made of coconut leaves, and banana suckers, suggest themselves as being the most likely media for the accidental conveyance of scale in this way; although in the case of the former, at any rate, it would be necessary for *Aspidiotus* larvae to be hatching when the material arrived at its destination in order that the scale should survive.

Secondly: insects, birds, or fruit-bats ("flying foxes") may fly from tree to tree with scale adhering to them. It is probably in this way that scale spreads from place to place in any one continuous land area. A striking instance of this was noted at Nagasau (Taveuni) in 1931. Scale was abundant on almost every kavika (*Eugenia*) tree throughout the whole estate, and spread later on to every coconut growing round each kavika tree. The latter did not occur in groves, but were scattered at irregular intervals, and it would seem certain that scale must have been spread through this estate by some flying animal which frequents kavika trees—whether insect, bird or bat was not ascertained.

Thirdly: spread can be effected by the locomotion of the scale-insects themselves. This is only possible when the insects are in the larval stage, and can only cause very limited spreading. The minute scale larvae are slow but persistent walkers. They cannot fly, and it is certain that they are incapable of walking along the ground from tree to tree.

Wind probably plays very little part in the dissemination of scale. If it were of any importance in this respect one would expect to find the pest spreading from tree to tree down wind. But such an occurrence is not particularly noticeable; in fact, there is generally a noted absence of wind in places where scale is abundant.

Nature of Damage.

Aspidiotus destructor, which in Fiji was chiefly a pest of coconuts and bananas, feeds mainly upon the undersides of the leaves, but in badly attacked areas it is usually to be found on the uppersides of the leaves also, as well as on the leaf-stems, flower-spikes, and fruits. It causes no direct harm, however, to anything but the leaves, and is essentially a leaf-destroying pest. In severe outbreaks the insect

reaches such abundance that it forms a continuous yellowish crust all over the under-sides of all the leaves, countless thousands being present on every coconut tree or banana plant. It causes premature death of the leaves by sucking their juices and obstructing the stomata. Attacked leaves first turn yellow, then wither and die, and a reduction in the vitality of the whole tree or plant results. The yellowness of scale-infested coconut trees renders them very conspicuous at long distances, and severe attacks produce that stunting of the new leaves which was such a noticeable sequel to outbreaks of *Levuana*.²⁹

The Scale Position in Fiji in 1927.

Although the damage caused by *A. destructor* was not so generally severe as that which had been caused by the *Levuana* moth, we have in certain places seen trees completely defoliated by scale; and many trees growing in poor soil, or ill-nourished owing to overcrowding, were killed outright after two or more attacks.

The heaviest defoliation by *A. destructor* seen by Paine in 1927 was on the islands Wakaya and Koro. All along the eastern side of the last named island is a coastal flat densely planted with coconuts. It is native-owned land, and as many as 75 trees were counted in a sample quarter-acre just north of Mudu.* Scale outbreaks occurred at intervals up this coast, and owing to the facilities for rapid spread occasioned by the overlapping leaves of adjacent trees, the attack was exceptionally severe. Outbreaks almost as severe as that just mentioned were seen on Gau and Moala.

On the southern coast of Vanualevu there was an almost continuous belt of scale-ridden trees extending round Savu-savu Bay, and from Savu-savu Point almost to Salt Lake. The trees on the immediate foreshore, which is exposed to the S.E. trades, escaped attack. But behind them, in the shelter, patches of yellow-leaved, scale-ridden trees could be found almost anywhere.

On the Wainunu River scale had been intermittently bad over an extensive area since 1924. In 1927 almost the whole of Muanicula estate was yellow with scale, and although individual trees did not seem to suffer quite such complete defoliation as was the case on Koro, the Wainunu outbreak was remarkable for the thoroughness with which the pest spread through the estate. It was perhaps the most extensive single outbreak there has ever been in Fiji, and covered an area of about a thousand acres, in which practically every tree was badly attacked.

Owing to the succession of hurricanes that visited Fiji during the years immediately succeeding that in which the complete control of *A. destructor* took place, it is unfortunately not possible at present to state in terms of copra output the extent to which scale was directly responsible for a reduction in that crop; the benefit derived from the introduction of *Cryptognatha nodiceps* having in most places been masked by the subsequent ill effects of the hurricanes and 1930 drought.

What made the planting community in Fiji view this pest with particular dismay was the alarming rapidity with which it spread from island to island, and the consequent inconvenience both to planters and shippers occasioned by the stringent restrictions on inter-island shipping, which were an essential part of the anti-scale campaign launched by the Department of Agriculture.

In 1927 Taveuni and almost all the Lau islands were free from scale, and these places produce more than half Fiji's crop of copra; so that before the pest had been brought under control the prevention of its further spread was a matter of the gravest importance.

Neither chemical nor mechanical methods of control for insects attacking coconuts can satisfactorily be employed in Fiji, where labour is expensive and comparatively

* This is just four times the density of trees properly spaced at 30 ft. intervals.

scarce, where coconut estates are not sufficiently concentrated to allow a power sprayer to be used without incurring excessive transportation costs, and where the trees are not habitually climbed for the harvesting of the crop. Thus the severity of the scale position in Fiji at the beginning of 1927 demanded special efforts towards obtaining effective biological control, and to this end a number of Coccinellid beetles recorded as attacking coconut scale in Trinidad were investigated in that country from September 1927 to March 1928.

IV. NATURAL CONTROL OF *A. DESTRUCTOR* IN FIJI PRIOR TO 1927

(by R. W. Paine).

Climatic Factors.

In contrast to attacks by the Coconut Moth, *Levuana iridescens*, which often reached a condition of extreme severity in every place where coconuts were growing within the geographical range of the pest, outbreaks of *Aspidiotus destructor* seemed to occur only in more or less circumscribed areas within the confines of any one island; and although this scale suffered from the depredations of quite a large assortment of natural enemies, we are convinced that prior to 1927 the limits imposed on its spread were in large part due to climatic factors. On the other hand, its rapid spread in an easterly direction along the south coast of Vanualevu in 1927, and its complete absence at that time on Taveuni, and on all the Lau islands (except Moala) are clear indications that the insect had not at that time colonised all the territory favourable for its existence in the Fiji Group as a whole.

The ultimate limits of its spread on Vanualevu before it was finally brought under control in 1927 correspond fairly closely with the boundary between the wet and dry zones of this island, *i.e.*, a line drawn from Bua Bay to a point about half way up the N.W. coast of Natewa Bay. South of this line *Aspidiotus* was rife; north of it the scale was very generally absent, except for one small area on the lower Dreketi River. It failed, however, to reach the Natewa peninsular.

In Vitilevu, moreover, although outbreaks were comparatively small and of short duration, the insect was notably more abundant in the south-eastern than in the north-western half of the island.

The occurrence of this pest would seem, therefore, to depend very largely on the combined effects of wind and rainfall. But the fact that coconuts occur in greater abundance and have a more continuous distribution in the wet zone than in the dry zone of the largest islands must in this connection not be lost sight of. Such concentration of the food supply is in itself of considerable importance as a factor favouring the spread of this pest; as could be readily appreciated by a traverse along any section of coastline where closely planted (or rather self-sown, usually native-owned) areas of coconuts alternated with belts of forest and with more regularly planted estates. Scale attack was almost always more severe in the former.

In brief, it could be said that the stronghold of *A. destructor* in Fiji consisted of those districts in the wet zone where coconut trees occurred in dense plantings (100 or more trees to the acre); and that outside such areas outbreaks were, with a few notable exceptions, non-existent or else of a purely transitory nature.

Such conclusions as we have been able to draw regarding the operation of climatic factors in the control of *A. destructor* in Fiji are largely based on a study of outbreaks in the field and lack the support of any carefully controlled experiments to ascertain the relative importance of wind, rainfall, degree of exposure, and so forth.

During observations on scale-infested seedling coconuts in 1927 Paine noted that the leaf area covered by living scale more than doubled itself after one generation on plants kept inside an insectary and rendered ant-proof by a band of tanglefoot on the petiole of each leaf. Whereas on others, similarly tanglefooted and kept in the open, the scale infestation actually diminished by 50 per cent. Other tests and controls, run on similar lines, were started at the same time, but owing to the difficulty of obtaining a sufficient number of seedling palms on which the initial scale infestation and the proportion of female scales was exactly the same, insufficient data were obtained to allow of any reliable generalisations being made.

Trees exposed to strong winds are seldom if ever subject to attacks of *A. destructor*. The scale is, therefore, seldom found on the tall coconut trees which usually form the littoral fringe of a plantation. It is interesting to note as a corroboration of what we have just said about wind that the scale on some seedling palms, kept on the deck of a steamer as food for *Scymnus* colonies, rapidly died after a few days' exposure to strong wind. In this situation no predators could have attacked the scale, nor were they splashed with salt-water spray.

We have already remarked on the preference shown by *A. destructor* for areas of closely planted coconuts. This is probably due to the fact that in such situations there is greater protection from the wind and therefore greater facility for spread than there is in places where the host-plants are widely spaced. We are, therefore, of the opinion that wind is one of the most important factors governing the occurrence of scale.

An area in which the rainfall is considerable is apparently favourable to *A. destructor*; but where rainfall has been exceptionally heavy (e.g., at Wainunu in 1927) a high mortality from some disease results.

It has been stated in previous reports about scale outbreaks in Fiji that coconut trees growing in swampy places are particularly subject to attack. There are, however, no grounds in support of the oft-made assumption that *A. destructor* prefers ill-nourished to healthy, vigorous trees. The frequent occurrence of scale in areas of low-lying or swampy land would seem to be due to the fact that the coconut trees growing in such places are usually well sheltered from strong winds—a condition which we have seen favours the establishment of scale.

Excess Production of Males.

Apart from natural enemies, shortly to be discussed, there is one other factor which plays a considerable part in the curtailment of outbreaks of *A. destructor*. This is the occasional great preponderance of male scales in any one brood, to which reference has already been made. Here again further experiments are needed in order to elucidate the exact cause of this spasmodic and remarkable variation in the proportion of the sexes. That an almost completely all-male generation may succeed a generation in which at least 50 per cent. of the individuals were female we know to be of fairly frequent occurrence; and such a phenomenon is frequently antecedent to the concluding stages of a potential outbreak.

Natural Enemies in Fiji before 1927.

Besides the organisms which are known definitely to attack living *Aspidiotus*, it is convenient to include here reference to a few others, which, whilst commonly found in association with this scale, do not as a rule attack it whilst alive.

Snails.—The excrement of small snails is often to be seen on coconut trees infested with scale; and female scales which have been broken by some predator are generally to be found on such snail-frequented leaves. We have, however, no evidence other than this that snails feed on *A. destructor* in Fiji. Prof. T. D. A. Cockerell, when passing through Suva in May 1928, informed us that in Siam he found a snail (*Pupisoma orcula*, Benson) on coconut palms infested with *Aspidiotus*. If we are

right in attributing the damage remarked on above to snails, the latter must be ranked amongst the more important of the indigenous agents of natural control in Fiji.

Fungus.—A fungus with red spore-fruits, which project from the edge of attacked scales, is met with occasionally, and seems at times (e.g., Wainumu 1927) to be rather an important controlling agent. It is probably a species of *Nectria*, which was also present on small seedling palms brought with parasites of *Aspidiotus* from Java. Another fungus, of much more general occurrence, attacks the female scale-insects, and any eggs that may have been laid, and turns them a chocolate colour. No fruiting bodies have been observed, and it is possible that these symptoms are the result of some bacterial disease. On the whole fungus ranked amongst the more important agents of natural control on scale before 1927—more especially towards the later stages of an outbreak. Its spread is certainly accelerated by excessively humid conditions.

Mites.—Several species of mites are found in association with *A. destructor* in Fiji, but none seems to be actually predacious on the scale. *Pediculoides ventricosus*, Newp., although of wide distribution on coconut trees in Fiji, has never been recorded as attacking *A. destructor*. There is probably insufficient nutriment in one scale to satisfy a female mite of this species, and they are incapable of moving from one host to another once they have attained a certain size after feeding. The commonest mite met with on scale-infested coconut trees is a rather large black species, which appears to be a scavenger. Another species forms a webbing over the surface of the leaves; it was especially abundant on small palms kept inside our insectary in Suva. Its presence does not seem to interfere in any way with the normal activities of the scale.

Chelisoches morio, F.—This common tropical earwig is very abundant on coconuts and bananas in Fiji. It seems to be an insect of very varied habits so far as feeding is concerned. Simmonds²⁹ records this earwig as a predator on scale in Tahiti, where he observed it breaking open scales at night. Similar damage to scales in Fiji on plants frequented by *C. morio* can reasonably be attributed to this insect.

Anisorcus affinis, Crotch.—This is one of the commonest Coccinellids in Fiji, and is met with on almost every coconut tree. Several observers have remarked on it previously in this country in association with scale-insects. It is, however, only occasionally predacious on *A. destructor*, and is quite incapable of controlling by itself an outbreak of scale. It feeds on many other things beside scale (*vide*²⁹ p. 174), and frequents bananas as well as coconuts.

Scymnus sp.—This insect, although definitely predacious on *A. destructor*, is uncommon, and can play little part in the control of scale in Fiji. It was found rather plentifully on the Nadroga coast (Vitilevu) in June 1927, where it was the commonest predator in a small outbreak of scale on coconuts. The following month a few specimens of the same insect were found at Nabukelevu (Kadavu). It has also been seen at Nukulau and Lovoni; but was never found at Nasese, where an outbreak of scale was kept under observation for several months.

The life-history of this Coccinellid was studied in Suva with material brought back from Nadroga in June 1927. The eggs measure 0.30 by 0.18 mm., and are laid under the scales, being greenish yellow in colour, and when newly laid are difficult to see. The larvae are pink, slug-like, feebly hirsute, and rather sluggish in their movements; they lack white, waxy tufts. The pupae, in which stage the insect shows a gregarious habit, are also pink, but become darker in colour just before the adult emerges. They are more hairy than the larvae, and remain attached to the last larval skin on the surface of the leaf. The adults are black or very dark fuscous and measure from 1 mm. to 1.4 mm. only in length. The sexes could not be distinguished with a hand-lens.

The average life-cycle periods for the few individuals studied were as follows :—Incubation period 8·5 days, 1st instar 6·5 days, 2nd 3·5 days, 3rd 2·5 days, 4th 3·0 days, pupal period 5·5 days. The total development period in two instances was 29 and 31 days.

Both larvae and adults feed on *A. destructor*. During a period of seven days four adult beetles were observed to destroy 21, 32, 23, and 19 third stage female scales. Each beetle seems therefore to require only about 3 or 4 female scales a day to satisfy its hunger.

Scales which have been attacked by this insect lack any conspicuous external mutilation. The finely pointed mandibles of the *Scymnus* are inserted through the top of the scale and the soft body of the scale-insect is then chewed up, sucked and left as a shrivelled mass adhering to the inside of the scale at the place where the puncture was made. Only occasionally does this insect bite away the scale itself. When it does this the damage to the scale-insect cannot be distinguished from that occasioned by the attacks of ants.

Chilocorus nigritus, F. var.—At Mua (Taveuni), during the 1931–32 scale outbreak, a large black Coccinellid with a red head and shiny, much arched elytra, suddenly appeared in large numbers; being especially common on Kavika trees. The ladybirds were feeding on *Aspidiotus destructor*. Specimens were sent to the Imperial Institute of Entomology and were determined as a variety of *Chilocorus nigritus*. So far as we know this insect has not previously been recorded from Fiji, and the reason for its sudden abundance and equally sudden disappearance (*vide* p. 202) on Taveuni remains a mystery.

Other Coleoptera associated with Scale.—At least two other species of ladybirds have been seen on coconut trees attacked by scale. One of these has been determined at the Institute of Entomology as a species of *Anisomeristes* (fam. CORYLOPHIDAE). Although observed in the field to be feeding on scales of *A. destructor*, in captivity these beetles died when supplied only with living scales. It seems probable, therefore, that they are not predators, but that they frequent scale-infested trees where they derive an abundant supply of food from the dead and damaged scales which are always to be found there.

Monomorium floricola, Jerd.—This is the only species of ant we have observed in association with *A. destructor*. It is a minute brown ant, very commonly found on coconut trees in Fiji. It nests usually between the fibrous stipules ("vulu") in the head of a coconut palm. Paine observed this ant breaking open and carrying away healthy male pupae of *A. destructor* at Nasese; where it was also responsible for destroying a large number of *Spaniopterus crucifer* pupae from a piece of coconut leaf which had been pinned on a tree for the liberation of this imported parasite. This ant seems usually to be a scavenger and seldom attacks healthy scales, but its occasional wholesale destruction of living scales warrants its inclusion in a list of the natural enemies of *A. destructor* in Fiji.

Thrips.—Mr. H. W. Simmonds has informed us* that he found a thrips destroying scales in Suva in 1924. It attacked female scales parasitised by *Aphelinus chrysomphali* in addition to others which were healthy. The insect was sent to the British Museum for determination, but so far as we are able to ascertain was never determined.

In September 1927 Paine found a thrips, closely resembling one which had just been introduced from Java, on a scale-infested coconut tree at Savu-savu. It is scarcely possible that this could have been one of the introduced thrips, which had not at that time been liberated on Vanualevu; it was very probably the same species as that observed by Simmonds in 1924, and which had been seen from time to time subsequently. Nothing is known as to the extent to which this presumably indigenous thrips depends on *Aspidiotus* for its food supply.

* In a letter dated 13.xi.1931.

Insect Parasites.

The only insect parasites which are known to have been attacking *A. destructor* in Fiji prior to 1927 are the Chalcids, *Aphelinus chrysomphali*, Mercet, and *Aspidiotiphagus citrinus*, Craw. These were introduced by Simmonds from Tahiti in 1920^{20, 22}, but two discoveries make it desirable to state briefly the evidence for and against the theory that these two insects, which have of recent years been found in many localities to be attacking male and female scales, were generally distributed throughout Fiji prior to their importation from Tahiti. Firstly, a specimen, undoubtedly of *A. chrysomphali*, mounted on a slide by Knowles and obtained from Taveuni prior to 1920, was found in the Suva collection. Secondly, C. H. Knowles stated (also prior to 1920) that *A. citrinus* attacked *Diaspis rosae* in Fiji.

Knowles observed that the parasite *A. citrinus* attacked *Diaspis rosae*,* but stated that it only attacked male scales; moreover Jepson did not find it on *A. destructor*, although he examined thousands of this scale whilst engaged in the inspection of bananas for export. In 1927 Paine examined scale on many different plants in many parts of the Group and noted that *A. citrinus* was commoner and more generally found on male than on female scales.

These considerations suggest that there may be two biological races of *A. citrinus* in Fiji—a theory first proposed by Simmonds. One of these, originally parasitising *D. rosae* and possibly indigenous to Fiji, prefers the male scale of *A. destructor*; and another, introduced from Tahiti in 1920, which prefers the female scales.

With regard to *A. chrysomphali*, its appearance on Taveuni prior to 1920 does not necessarily indicate that at that time it was generally distributed throughout the Group. Apart from the fact that Taveuni is in many ways faunistically distinct from Vitilevu, it would seem to us unlikely that what is now such a common and widely distributed parasite on *A. destructor* should have escaped the vigilant notice of F. P. Jepson, during his frequent examinations of scale-infested bananas in Suva from 1912 to 1919, if it had been present on Vitilevu at that time.

That this parasite would, as *A. destructor* increased its territory throughout the Group, ultimately have spread from Taveuni does not vitiate our contention that the rapid dispersal and subsequent general establishment of this parasite throughout most of Fiji was brought about as a direct result of its introduction from Tahiti in 1920.

Colonies of the parasites introduced from Tahiti were liberated on the following islands during the years 1920–1925†:—*Vitilevu*: Nasinu (1920), Nasese, Nadi; *Moturiki* (1920); *Ovalau*: Bureta (1920), Levuka; *Gau*: *Batiki*; *Nairai* (1924); *Vannalevu*: Nabouwalu, Wainunu (1923 & 1924), Daria, Solevu, Dreketi; *Wakaya*; *Koro*; *Moala*; *Kadavu*.

The first colony of *A. chrysomphali* was liberated at Nasinu in April 1920. The insect became established there and spread rapidly. *A. citrinus* was first liberated at Moturiki in June of the same year, where it became established. It was taken shortly afterwards to Bureta, where later on it was found to be producing a parasitism as high as 90 per cent.

The liberation of these early colonies was carried out by Simmonds^{20, 21} who states that *A. chrysomphali* was at the time not present on Moturiki or Ovalau. The parasites spread rapidly, more especially *A. chrysomphali*, and subsequent colonies were almost all collected and liberated by planters and plantation inspectors, so that no very exact record of the strength or location of these colonies is available.

* We are unable to find any early published record of this, but Mr. H. W. Simmonds has handed us this information supplied to him verbally by Mr. C. H. Knowles, who was then Superintendent of Agriculture in Fiji.

† This information has been handed to us by Mr. Simmonds.

Simmonds is of the opinion that the majority of the colonies mentioned in the list above received material of both species of parasite; but that all the colonies contained both species remains open to doubt, neither is it certain that colonies of one or both of the parasites were not taken to localities not included in the list.

However, before entering upon a brief account of each individual parasite we should like to emphasize two facts in connection with their establishment in Fiji. Firstly, prior to 1920, there was no extensive parasitic attack on the female scales of *A. destructor* in Fiji. Secondly, that although by 1927 *A. citrinus* and *A. chrysomphali* were widely distributed and responsible locally for a fairly high degree of parasitism, they did not exercise a sufficient control on the scale to prevent its rapid spread and extensive damage to the coconut crop; and on that account these parasites are seen to have been of only very minor importance in the campaign of biological control for *A. destructor*, which has recently been brought to such a satisfactory conclusion.

Accounts of the bionomics of these two parasites are included hereafter in the section entitled "Some Natural Enemies in Java," and it will suffice here to confine ourselves to a few observations which apply to Fiji only.

Aphelinus chrysomphali, Mercet.—This parasite is now very widely distributed in Fiji and has been found in the recent scale outbreak on Taveuni (p. 95). So generally distributed is it, that one can find it on almost any scale-infested leaf, no matter to what plant it may belong; and it would seem improbable that *Aspidiotus* could be accidentally transported in sufficient quantity to ensure its establishment in a scale-free area without this parasite being brought with it. And yet, in spite of its abundance, *A. chrysomphali* is seldom responsible for more than 5 per cent. destruction of female scales. In July 1921 Simmonds noted that 27 out of 28 female scales were attacked by this parasite in Suva. But the highest parasitism noted by Paine in 1927 was 20 per cent. at Korolevu (Nadroga). In most localities the parasitism is less than 5 per cent. On a seedling palm used for experiments in Suva a 35 per cent. parasitism was found on one occasion. We have already suggested that even if it had not been introduced from Tahiti this parasite would ultimately have spread independently from Taveuni right through the Group. Our grounds for this contention arise from at least two instances of striking self-spread, which provide about the only available proof of the capabilities of the insect in this direction. Simmonds found the insect established at Bua (Vanualevu) in 1922 at the time when he took the first colony of the Tahiti parasites there. And in 1931 we found it on Taveuni on *A. destructor*, which had not been on the island for at least the five previous years.

Aspidiotiphagus citrinus, Craw.—In Fiji this minute Chalcidid is neither so common nor so effective a parasite on *A. destructor* as is *A. chrysomphali*. There is reason to believe, as we have already noted, that two biological races of this insect may be present in Fiji, one of which prefers female, and the other male hosts. In a survey of scale outbreaks on Vanualevu in 1927 we observed that the male scales were parasitised by *A. citrinus* in nine out of ten localities from which scale samples were examined; whilst the female scales were parasitised by it in eight of these localities. The form attacking female scales is, therefore, now widely distributed, and in no instance has it been reported as absent on islands where scale has been found. Simmonds informs us that shortly after the first colonies of the Tahiti stock had been liberated on Moturiki and Ovalau, parasitism of female scales reached as high a figure as 90 per cent. (Bureta). This is far in excess of any degree of parasitism observed by us in 1927. The highest figure we noted for parasitism in female scales by this species was only 5 per cent. (Muanicula); and in Suva this parasite was so uncommon that it did not figure at all in a list of natural enemies recorded as operating against *A. destructor* on seedling palms under observation at the laboratory. Although now widely distributed through the Colony, its occurrence

throughout any area of scale is very uneven, and the sum total of its destruction of scale must be negligible.

V. SOME NATURAL ENEMIES IN JAVA.

In the latter half of 1926 a general survey of the natural enemies of *Aspidiotus destructor* in Java was made by the writer. At the same time the more common parasites of the two other species of scales which are abundant on coconut palms in that country, namely, *Aspidiotus palmarum* and *Chrysomphalus ficus pallens*, were investigated to some extent for comparative purposes.

It was unfortunately impossible, on account of the very limited time available, to make a really thorough survey of the part played by parasites and predators in controlling the scale. It was, however, possible to come to a decision concerning the relative importance of the various insect enemies, and to study their early stages sufficiently to enable us to devise methods for shipping them to Fiji. Attention was also paid to the means of recognition of the larvae and pupae of the various species *in situ* in their hosts; and in the separate accounts of the parasites which follow, special reference is made to those features which were found to facilitate identification in the field with the aid of a hand lens only.

The bulk of the material was collected in the neighbourhood of Buitenzorg (West Java), but in addition, collections were made near Pekalongan (Central Java) from time to time. Also, through the kindness of Dr. Leefmans of the Instituut voor Plantenziekten, batches of parasitised scales were obtained from a few other widely separated localities.

In the course of this work the opinion was formed that insect enemies are not the most important controlling factors in Java. Both parasites and predators are abundant wherever outbreaks of the scale occur, but the rate of destruction of scales by insect enemies does not appear to check the outbreaks before they are checked in any case by climatic or other factors. In the wetter parts of the country serious outbreaks rarely occur and the scale can only be found in small isolated batches. Such batches are often highly parasitised and it is not unusual to find the proportion of parasitised scales to be as high as 90 per cent., but even this percentage is often insufficient to prevent the scale from increasing. The scarcity of scale in these areas appears to be due rather to bacterial or fungous agencies, which are themselves influenced by climatic conditions, than to insect enemies. There is, however, no doubt that the insect enemies play an appreciable part in reducing the multiplication of scale, although they do not prevent it. The exact part played by climatic conditions was not determined, but in the wetter areas it was very frequently noticed that large batches of scale died off suddenly and completely, when immature, without having been attacked by either parasites or predators.

The parasites reared from *Aspidiotus destructor* were:—*Aphelinus chrysomphali*, Mercet, *Comperiella unifasciata*, Ishii, *Spaniopterus crucifer*, Gahan, *Chiloneurinus microphagus*, Mayr, *Casca parvipennis*, Gahan, *Aspidiotiphagus citrinus* var. *agilior*, Berlese, *Physcus varicornis*, How. var. *intermedia*, Gahan, and "an Encyrtid, genus near *Thomsoniella*." Of these, only the first is an external parasite. All the others are true endoparasites in all stages except as adults, and in most cases even the adults spend at least 12 hours in their hosts before freeing themselves.

The parasites reared from *Aspidiotus palmarum* were not nearly so numerous as regards species as those from *A. destructor*. They were *Aspidiotiphagus citrinus*, *Casca parvipennis*, and *Aphelinus chrysomphali*. *Chrysomphalus ficus pallens* was attacked by *A. citrinus*, *C. parvipennis*, *A. chrysomphali*, *Comperiella bifasciata*, *Physcus varicornis*, and *Chiloneurinus microphagus*.

The three scales in question were frequently found together on the same coconut leaf, and sometimes even on the same leaflet, and since they are similar to one another in general form, except as regards the degree of hardness of their scale-coverings, it might be expected that they would be attacked by the same natural enemies. This, however, is by no means the case. It is true that *Aphelinus* sp. and *Aspidiotiphagus* sp. which have a very wide host range, attack these three scales equally commonly, but *Physcus* sp. and *Chiloneurinus* sp., though attacking both *A. destructor* and *C. ficus*, show a marked preference for one species; and *Comperiella* spp. and *Spaniopterus* sp. appear to be entirely restricted to one scale on coconuts, though not the same species in each case. Although the two species of *Comperiella* are almost identical in all stages, *C. unifasciata* parasitises *A. destructor* only, and *C. bifasciata* attacks *C. ficus pallens* only. *Spaniopterus crucifer* appears never to parasitise *A. palmarum* or *C. ficus pallens*, and in captivity it could not be induced to oviposit in these scales although it attacked *A. destructor* readily in identical circumstances. This might be attributed to the fact that the scale-covering of *A. destructor* is very soft as compared with that of *A. palmarum* or *C. ficus*; but in the case of *C. unifasciata* it cannot be assumed that its failure to attack *C. ficus* is due to the relative hardness of the scale-covering, since the almost identical *C. bifasciata* always confines itself to the harder scale. In Japan *C. unifasciata* attacks *Pseudonidia duplex*, and *C. bifasciata* attacks *Chrysomphalus aurantii* and *C. aonidium*. These three scales are similar to *C. ficus pallens*, but much harder than *A. destructor*. It is likely that both species of *Comperiella* have other hosts on other food-plants in Java, and it is therefore surprising that they exhibit such a marked specificity in their choice of hosts on coconuts.

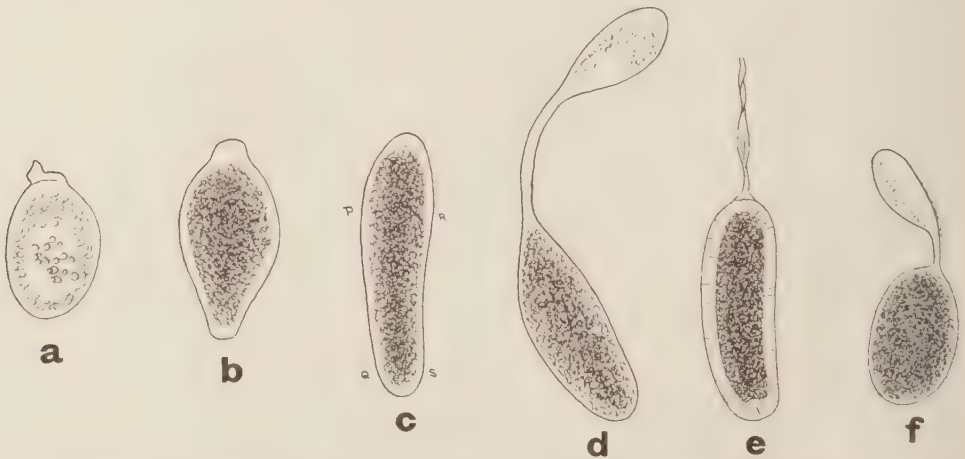


Fig. 2. Eggs of scale parasites: a, *Aphelinus chrysomphali*; b, *Casca parvipennis*; c, *Physcus varicornis*; d, *Spaniopterus crucifer*, mature egg from oviduct; e, *Comperiella unifasciata*; f, "An Encyrtid, genus near *Thomsoniella*."

The habits of the common internal parasites found in Java were studied to some extent, and were found to be very similar in all species, as must necessarily be the case. Before outlining the life-history of each species separately it will be well to consider in a general way the nature of the few specific differences in habits and structure which do exist.

The eggs in all cases are laid right inside the body of the host, the ovipositor of the parasite penetrating both the scale-covering and the cuticle of the scale-insect. But whereas the eggs of some species are free and quite unattached to any of the organs of the host, others are permanently attached by means of long flexible stalks

to the body-wall, so that they are suspended freely in the body-fluid but are not entirely free. Considerable differences in shape are noticeable (fig. 2), and the shape is constant for each species.

The larvae are all remarkably transparent, so that their internal anatomy is readily seen through the transparent cuticle of the host. In nearly all cases it was found possible to identify the different species accurately without killing the larvae or removing them from their hosts. The most useful features for this purpose are the distribution of the fat-body, the shape of the stomach, the distinctness of the segmentation, the relative size of the segments, and the form of the tracheal system. The mandibles and buccal thickenings (fig. 3) also show constant specific characters, but it is usually necessary to remove the larvae from their hosts before these can be seen clearly.

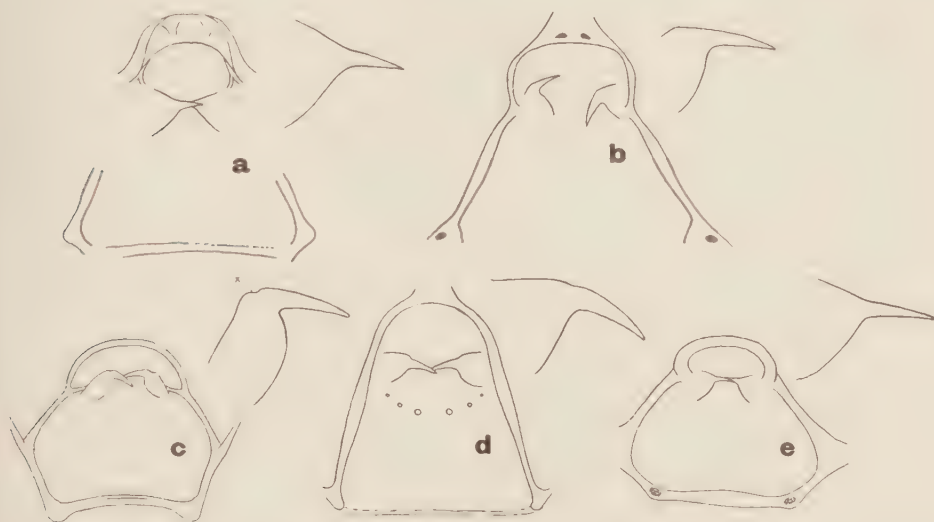


Fig. 3. Mouth-parts of larvae of scale parasites: a, *Aphelinus chrysomphali*; b, *Casca parvipennis*; c, *Spaniopterus crucifer*; d, *Phycus varicornis* var. *intermedia*; e, *Comperiella unifasciata*.

Important differences in the shape of the larvae occur, and these are chiefly due to their orientation in their hosts. Some species always lie in a curved position on their sides, while others always lie on their dorsal or ventral surfaces. All species, especially when young, are capable of moving actively about in the semi-fluid contents of the host by means of a wriggling movement, but those which are curved are incapable of turning over or of straightening themselves out completely and can only bend in the dorso-ventral plane, while those which are straight and lie on their backs or fronts are incapable of turning on to their sides and can only bend in the lateral plane.

All species normally devour the whole of the contents of their hosts before preparing to pupate, so that they eventually lie freely inside the transparent cuticles, as if they were enclosed in minute glass boxes (fig. 12). Moreover, all of them pupate inside their hosts, after having excreted and undergone a short prepupal period. At this stage, however, there are certain highly characteristic features which are constant for some species. These are the distribution and colour of the excrement inside the host, and the position which the larva takes up preparatory to pupating.

The pupae are incapable of movement in all species and are held firmly in position by the pressure of the dorsal and ventral walls of their hosts. They can be identified by their shape, colour, the distinctness of the abdominal segments, and orientation within their hosts.

The adult parasite emerges in all cases by biting a hole in the dorsal wall of the scale. The size of the hole (relative to that of the scale), the degree of regularity of its outline, and its position in the host, are constant, within reasonable limits, for most species (fig. 4). It was often found desirable to decide what species of parasite had occupied parasitised scales from which the adults had already emerged, and the exit-holes were found very useful for this purpose. An additional means of identifying the departed parasites is afforded by the excrement (fig. 4), which remains unaltered in form and position long after the parasites have escaped.

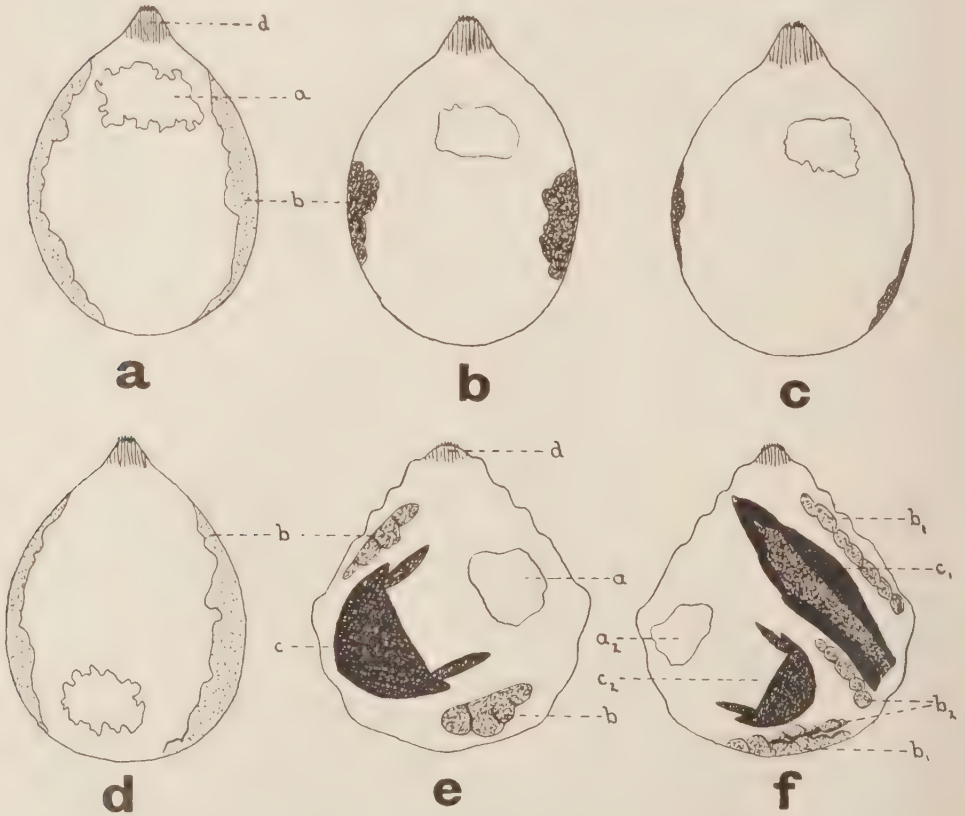


Fig. 4. Excrement and emergence-holes of scale parasites: **a**, *Comperiella unifasciata* in *A. destructor*; **b**, *Casca parvipennis* in *A. destructor*; **c**, *Spaniopierus crucifer* in *A. destructor*; **d**, *Chiloneurinus microphagus* in *A. destructor*; **e**, *Physcus varicornis* in *Chrysomphalus ficus pallens*; **f**, *Physcus varicornis* as a primary and secondary parasite in *C. ficus pallens*. **a**, exit-hole of parasite; **b**, excrement of parasite; **b**₁, excrement of primary parasite; **b**₂, excrement of secondary parasite; **c**, pupal skin of parasite; **c**₁, pupal skin of primary parasite; **c**₂, pupal skin of secondary parasite; **d**, pygidium.

The old pupal skin is left inside the host. In most species it is so transparent and flimsy that it can scarcely be detected, but in some it is strongly chitinised, so that it shows up as a conspicuous dark brown or black mass of characteristic shape inside the scale.

Superparasitism and hyperparasitism were found to be of frequent occurrence, though by no means in all species. Each species of parasite has its own peculiarities associated with these phenomena. Thus some species are always primary parasites, and some are both primary and secondary; and one, which is normally primary, often attacks individuals of its own species and matures as a secondary parasite therein. No parasites which are always secondary were found. Since the early stages of most species have transparent cuticles the secondaries are easily seen inside them, and it is usually easy to decide whether pupae found inside scales are primary or secondary by the distribution of the excrement, the size of the pupae, and the number present in each host.

Superparasitism occurs in many species, but whereas it results, in most species, in the death as young larvae of all the individuals except one in each host, in certain species more than one individual can mature in each host.

Most species show a marked preference for scales of a particular size and therefore age, though there is always considerable variation in this respect. Those species which normally attack full-grown (*i.e.*, 3rd stage) female scales very rarely attack younger ones and never attack males, and consequently the adults of these species are fairly constant in size. On the other hand, those which normally attack half-grown (*i.e.*, 2nd stage) female scales frequently attack both males and 3rd stage females also, and the size of the resulting adult parasites varies greatly according to the size of the host. No matter what size the host may be, the parasite larva is not ready to pupate until the whole of the body-contents have been devoured. Those species which attack both large and small scales commonly appear to be able to regulate their development to correspond with the food-supply, but those which normally attack large scales only are often unable to mature in smaller scales and die as larvae.

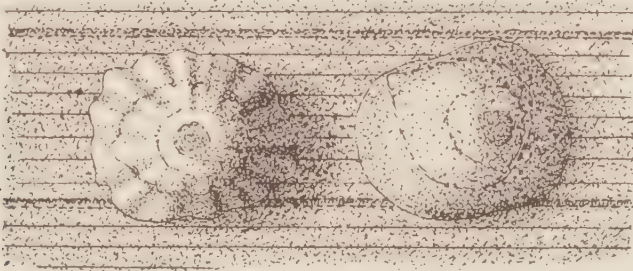


Fig. 5. Two full-grown *A. destructor* ♀♀ on coconut leaf, the one on the left parasitised, the other healthy (highly magnified). The two cast skins are seen in each case incorporated in the scale, while the outline of the scale-insect is visible through the scale.

No true secondary parasites were found, and the phenomena of superparasitism and hyperparasitism occurred only when those species which normally attack small female scales, or males, oviposited in larger scales. Hyperparasitism appeared in all cases to be accidental, to the extent that the parasites when ovipositing are unable to distinguish between healthy scales and those which are already parasitised, so that eggs are occasionally laid in larvae or prepupae of primary parasites which may or may not be the same species as those which are acting as hyperparasites.

Only one external parasite was found on coconuts in Java, and therefore no comparisons with others were necessary.

It may here be noted that parasitised individuals of *A. destructor* are readily recognisable in the field with the naked eye on account of the fact that the presence of a parasite, in any stage beyond that of half-grown larva, causes the host to be

distended and abnormally convex (fig. 5). The soft covering scale, which is ordinarily quite smooth and nearly flat is pushed out in the centre, and a number of folds radiating outwards from the centre are formed. Also, if a batch of *A. destructor* on a coconut leaf be held up to the light the contained parasite pupae, and sometimes the larvae, are readily seen in silhouette, in spite of their minute size.

It will now be convenient to consider briefly each species of parasite separately, beginning with the one external parasite.

1. *Aphelinus chrysomphali*, Mercet.

This Aphelinid has a very wide distribution, being recorded from several European countries, and from many tropical countries, including Africa, British Guiana, East Indies, Tahiti, and Fiji. Hence it probably occurs almost wherever suitable hosts are found. In Java and Fiji its distribution has been investigated by R. W. Paine and the writer, and it has been found in every locality in which *Aspidiotus destructor* is plentiful.

The principal recorded hosts are *Chrysomphalus dictyospermi* and *Aspidiotus destructor*. In Java it was found to attack in addition *A. palmarum*, *C. ficus pallens*, and several other Diaspine scales which were not identified. It undoubtedly has a very wide range of hosts.

The males are greatly outnumbered by the females but are nevertheless of common occurrence. This is noteworthy in view of the fact that in certain allied species of *Aphelinus* males are extremely rare.

Description of Stages.

Egg (fig. 2, a).—The egg is elliptical and transparent. Its length is approximately twice its width. One end is uniformly rounded and the other (the micropylar) end is bluntly pointed and bears a short appendage which is varied in form but is usually bent twice on itself so as to form a hook. This appendage appears to be the remains of a large vesicle which is distended when the egg is in the ovary but shrivels on account of the absorption of its contents when the egg is laid. When the egg is maturing in the ovary it is shaped like a sausage divided into two portions by a very slight constriction near the middle. Both ends are rounded but the slightly longer portion is a little narrower than the other. The smaller and more rounded portion is the egg proper, and the other part presumably shrinks and is reduced to a mere appendage on the former. The constricted area corresponds to the stalk which joins the egg proper and the vesicle in the case of *Comperiella unifasciata*, but in the present species it is so short that it can scarcely be described as a stalk.

Larva (fig. 6, h).—The larva changes very little, except in size, during its development, and it will suffice to describe the full-grown larva only, which like the young, is very transparent and colourless, except for the gut, which is dark green or brown and opaque on account of the contained food. There are fourteen clearly marked segments, including the most anterior on which the mouth opens. This first segment is small and button-like, but the remainder are all approximately equal in length. When viewed dorso-ventrally the larva is roughly oval in shape, and its greatest width is a little more than two-thirds of its length. The anterior end is nearly semi-circular, the greatest width being at the sixth segment, and the posterior half tapers rapidly to the blunt anal extremity. When viewed laterally the larva is seen to be somewhat flattened, which becomes more marked as it grows. The fat-body, gut, mouth-parts, and the main tracheal trunks, are clearly visible when the larva is examined by transmitted light, but the other organs are invisible on account of their extreme transparency. The fat-body occupies the lateral portions of all the segments from the third to the last. The second segment is perfectly transparent, the oesophagus being invisible. The stomach is broadly oval; it extends from the

fourth segment to the tenth or eleventh and occupies an unusually large part of the body cavity. Since the larva is ectoparasitic the tracheal system is well-developed and present throughout the larval life. There are eight pairs of spiracles, *i.e.*, one

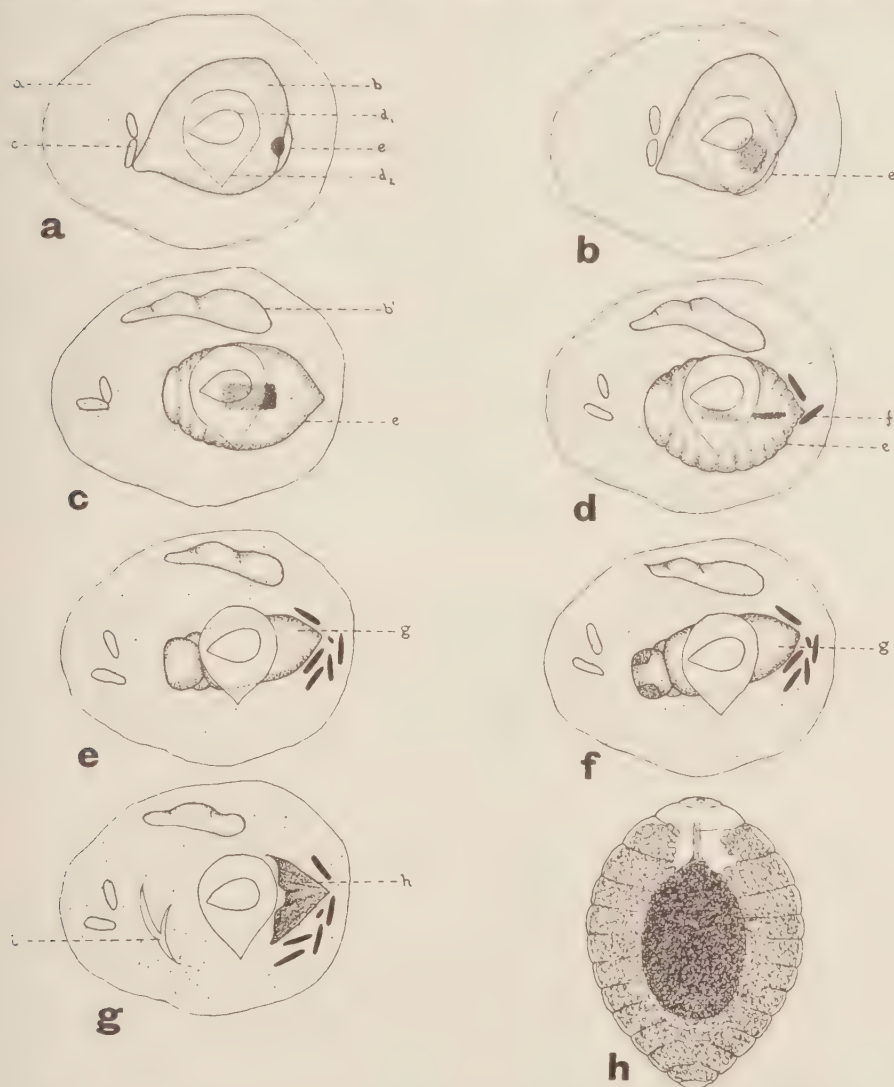


Fig. 6. *Aphelinus chrysomphali*, a-g, development of parasite, with *A. destructor* as host (diagrammatic); h, full-grown larva, as seen by transmitted light: a, scale; b, mature ♀ of *A. destructor* which has shrunk a little where parasite has fed upon it; b₁, remains of host after parasite has ceased feeding; c, 2 eggs laid by the scale-insect before it was attacked by the parasite; d₁, d₂, first and second cast skins of the scale-insect incorporated in the scale; e, parasite larva at successive stages of growth (full-grown at e, and beginning to excrete at d); f, faeces of parasite; g, parasite pupa; h, pupal skin of parasite; i, emergence slits made in scale by adult parasite (usually only one slit).

pair on each segment from the third to the tenth. The distance between the first and second spiracles on either side is approximately twice the distance between

any other adjacent ones. The two transverse commissures lie dorsal to the gut in the second and eleventh segments respectively. The mandibles (fig. 3, **a**) are not very strongly chitinised; each consists of a sharp narrow spine projecting from one corner of a broad triangular base. There is a semi-circular thickening of the cuticle on the dorsal side of the mouth, and a transverse thickening on the ventral side (fig. 3, **a**).

Pupa (fig. 7).—The pupa varies considerably in colour. It is usually a rich, light yellow-brown, but another form is very pale yellow, and very small pupae are often almost colourless. The colour is due in the first place to the pupal skin, and since the adult is yellow and the pupal skin is transparent, despite its colour, no marked colour changes occur in the pupal stage. Also, dark yellow pupae produce dark yellow adults, and pale pupae produce pale adults. There are usually no surface markings, except when the brown band mentioned hereafter is present. The pupa is very shiny, and very greatly flattened (fig. 7, **b**). The dorsal surface is invariably in contact with the leaf, the ventral surface being in contact with the covering scale, and therefore the dorsal surface is quite flat, or sometimes slightly concave, while the ventral surface is always slightly convex. On account of the contact of the dorsal surface with the leaf and the extreme softness of the pupal skin, especially at the time of pupation, the sutures on the dorsal surface are almost obliterated. The outline of the pupa is very constant in form, and in this respect this species differs from those of internal parasites, whose pupae often vary greatly in shape. The sheaths of the appendages are very closely incorporated into the ventral surface, but the sutures between them are much more apparent than those on the dorsal surface.

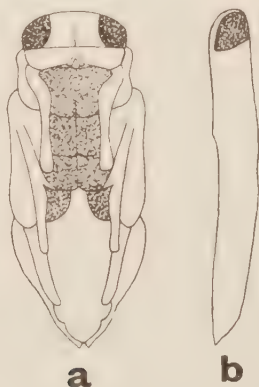


Fig. 7. *Aphelinus chrysomphali*, pupa: **a**, ventral; **b**, lateral.

The foregoing description of the pupa applies to nearly all specimens parasitising *Aspidiotus destructor*, but pupae which are enclosed in the scales of *Chrysomphalus ficus* or *Aspidiotus palmarum* usually differ from this type in one striking respect, though no fixed rule can be made. Pupae from the two last-named scales nearly always have a very obvious, dark, reddish-brown, longitudinal band in the middle of the ventral surface extending from the first thoracic segment to the first abdominal (fig. 7, **b**). The width of this band is equal to about a third of the total width of the pupa, but at its posterior end it is broader and forked. There seems no doubt that these two forms are the same species, especially as intermediate forms occur, but the different appearance of those pupae possessing the dark brown band led us for a long time to conclude that two different species were present. The form with the dark band has never been found in Fiji but is abundant in Java in the hosts named above.

Life-history.

A. chrysomphali is a primary external parasite of several species of Diaspine scale-insects. It was the only external parasite found to attack the coconut scales in Java. The early stages are all spent under the scale-covering, but outside the scale-insect. Second and third stage female scales are attacked by this parasite, which also attacks male prepupae and pupae. A very decided preference is, however, shown for full-grown females, including those which have already begun ovipositing. Male scales are attacked commonly only on those occasions when entirely male generations occur. The adult parasites resulting from male and second stage female scales are undersized as compared with those from mature females. *Aspidiotus destructor* is attacked far more frequently than either of the other two species. *A. palmarum* is very rarely attacked, and *C. ficus pallens* is intermediate in this respect.

Egg.—The egg is usually laid under female scales which have already passed the second moult. Scales which have already laid a few of their eggs are preferred, but those which have laid nearly all their eggs are usually avoided. The egg of the parasite is always situated between the scale-insect and the leaf. If the host is lifted with a needle the egg remains attached to it and can then be seen fairly easily. There is, however, no definite means of attachment, and it is only the extreme stickiness of the egg and the lower surface of the host which causes it to adhere.

Superparasitism occurs commonly, but more frequently when *C. ficus pallens* is the host than in the case of *A. destructor* or *A. palmarum*. It is possible for as many as four parasites to feed on one host simultaneously and to reach maturity, but such individuals are invariably small. The largest number of eggs found on one host was five.

Larva.—The larva begins to feed as soon as it leaves the egg. It feeds by puncturing the ventral skin of its host with its mandibles and sucking out the body-contents, the mouth area being pressed closely against the skin of the host to form a sort of sucker. The activities of the host cease as soon as the parasite begins feeding, but the host does not actually die until about a day later. Although the scale-insect is not affected in any way at the time the egg is laid, and even continues ovipositing, if of a suitable age, with the egg of the parasite upon it, the effect of the larva appears to be immediate, and oviposition, if already commenced, ceases as soon as the egg of the parasite hatches.

The larva grows with great rapidity, and as it grows the body of the host shrinks, until finally there is little left of the host except the shrivelled skin (fig. 6). The space formerly occupied by the scale-insect is occupied by the full-grown larva of the parasite, and the remains of the host are pushed to one side. In fig. 6, the two eggs which the scale-insect had laid before it was attacked were not devoured, but in those cases where eggs of the parasite are laid on hosts which have already laid most of their eggs, the body of the parent scale-insect in each case having shrunk correspondingly, the parasite larvae feed on the eggs instead. They were definitely observed biting the eggs with their mandibles. Being almost as broad as it is long and entirely without appendages, the larva is almost incapable of locomotion. When feeding upon a scale-insect, rather than on eggs, there is no need for it to move at all. But when feeding upon eggs it is necessary for the larva to advance from time to time and this it does by a series of alternate and very slow contractions and expansions of the body, accompanied by lateral twists. During the contractions the anterior third of the body is almost completely telescoped into the remainder. The body is very sticky and adheres to the covering scale and the leaf, and this property serves to facilitate locomotion.

The presence of the full-grown larva under the covering scale of *Aspidiotus destructor* causes a very noticeable increase in the convexity of the covering-scale. This is a useful point when material is being collected in the field. No such distention

occurs in *A. palmar* or *C. ficus pallens* on account of the greater rigidity of the covering scale in these species.

No excretion occurs until the larva is ready to pupate. The excrement is in the form of small, shiny, black or brown bodies, bluntly pointed at each end (fig. 6), and usually 5 or 6 in number, and uniform in shape. They are deposited inside the scale, round the posterior end of the larva, and are so conspicuous in *Aspidiotus destructor* that they are very useful as a means of detecting the full-grown larvae or pupae *in situ*.

Pupa.—The pupa is incapable of movement of any kind and changes very little in colour during its development, since the adult also is yellow. It always lies with its back against the leaf.

Adult.—The adult, when ready to emerge, breaks the pupal skin ventrally, and then, if *A. destructor* is the host, it usually bites a slit in the covering-scale to effect its exit (fig. 6, g). The slit is curved so that a part of the scale can be turned back like a small trap-door. No actual hole is made because the parasite does not bite out the piece of the scale completely. In this respect it differs from all the internal parasites. Sometimes it does not bite the scale at all but simply pushes its way under the edge of it. In the case of the harder scales, such as *Chrysomphalus ficus*, it is impossible for the parasite to make anything in the nature of a flap, and therefore it bites an irregular and elongate hole. This hole is quite unlike any of the holes made by the internal parasites and can be confused only with the holes made by the predatory Coccinellids. The pupal skin of the parasite and the excrement of its larva remain inside the scale after the adult has emerged.

The adult is very active, crawling over the leaves in an erratic and characteristic manner, but does not fly very often. The ovipositor is inserted through the scale (never under the edge of it) at a point just above the edge of the contained scale-insect, then passing underneath the latter, and the egg is laid between it and the leaf.

The feeding habits of the adult are interesting. In captivity it thrives on honey and water only, but there is no doubt that it frequently feeds on the body juices of some of its hosts in nature. The only species on which it was observed to feed is *Aspidiotus destructor*, and it is certain that it never feeds on hard scales. When about to feed on a scale-insect the parasite first faces away from the centre of the scale and punctures it with its ovipositor. A minute drop of fluid exudes from the puncture, and the parasite then turns round and sucks up the fluid. Quayle, writing of *Aphelinus diaspidis* as a parasite of *Chrysomphalus aurantii* in California, says: "Some of the Chalcid parasites of scales have been recorded as feeding at the puncture holes made by the ovipositor. This has not been observed in the case of *Aphelinus diaspidis*. . . . We are not sure that any liquid would be exuded in the case of a puncture in the scale covering of some of the armoured scales." Observations in Java confirm these remarks so far as the hard scales are concerned, though the parasite in this case is *Aphelinus chrysomphali*. Experiments were made with *Chrysomphalus ficus*, under the same conditions as for *Aspidiotus destructor*, but the parasite never attacked it except for the purpose of ovipositing. Certainly *A. destructor* is much better adapted for feeding purposes than any of the hard scales, on account of the thinness and delicacy of the scale-covering and its intimate contact with the scale-insect beneath. When the ovipositor is inserted into the scale-covering for the purpose of oviposition no fluid exudes, because the scale-insect itself is not punctured, and it is therefore clear that the puncturing of the scale-insect serves solely for feeding purposes and is not connected in any way with oviposition.

The adults live in captivity from 6 to 22 days, but live much longer when they are not given any opportunity to oviposit.

A consideration of the habits of the adult parasite leads to some interesting conclusions concerning the species of scale selected for oviposition. The covering

scale of *A. destructor* is so flat and delicate that it is no protection against parasites. That of *C. ficus pallens* is higher and much tougher, and the scale-insect does not fit it so closely; and the scale-covering of *A. palmarum* is still higher and thicker and harder. There seems little doubt that the parasite's choice of host depends largely upon the facility offered by each species of scale for penetration by the ovipositor. It is significant that *A. palmarum* is very rarely attacked by this parasite at any age, or by any other parasite except when young.

Life cycle.—This is approximately as follows:—Incubation of egg 3 days, larval period 5–6 days, pupal period 4–6 days, oviposition to emergence 14 days (mean). Dissections showed that the eggs are not mature when the adults emerge, and apparently about 3 days elapse between emergence and the commencement of oviposition.

Natural Enemies.

Aphelinus chrysomphali has no regular predatory enemies, and the common predators of *Aspidiotus* and *Chrysomphalus* (Coccinellids and the Thrips) seem, in Java, to avoid scales parasitised by it as a rule. When the percentage of parasitism by it is high, however, its pupae are very frequently attacked by the Coccinellids, and undoubtedly it is occasionally attacked by all the predators which destroy its host.

Attacks by secondary parasites on *Aphelinus chrysomphali* are very rare. On one occasion a pupa was found to have a Chalcid larva feeding on it externally, and later this larva pupated under the scale-covering and eventually produced a black adult. *Casca parvipennis*, which sometimes parasitises the primary internal parasites of *Aspidiotus* and *Chrysomphalus* but is usually a primary parasite itself, occasionally attacks the pupae of *Aphelinus* and reaches maturity in it. With these exceptions there appear to be no natural enemies of this parasite in Java.

2. *Comperiella unifasciata*, Ishii.

This Encyrtid has been recorded only from Japan and Java. It has been imported into Fiji, but probably is not established there. It was found very plentifully in both Central and West Java and is probably widely distributed throughout the island.

In Japan this insect was bred from *Pseuduonidia duplex*, and in Java from *Aspidiotus destructor*. Apparently, the other common coconut scales in Java, *Aspidiotus palmarum* and *Chrysomphalus ficus*, are never attacked by it in nature, although the latter is commonly attacked by *C. bifasciata*. There is no doubt that *A. destructor* is its principal host in Java. It was found abundantly in all localities where this scale occurred. It is never a secondary parasite.

The male is extraordinarily rare. In a period of five months, during which many hundreds of specimens were collected in various localities and bred in the laboratory, only one male and one gynandromorph appeared. For three months the only indication of the existence of males was a remarkable gynandrous specimen. The true male emerged from a large batch of scales heavily parasitised by this species. It should be mentioned that no differences, except in point of size, could be found between this male and the males of *C. bifasciata* in the collection of the United States National Museum; there is, however, very little doubt of its identity.

It is clear that *C. unifasciata* must be largely parthenogenetic and thelytokous. Only one generation from a known parent was bred right through in the laboratory; the parent was a bred, unmated female, and the progeny were entirely female.

Description of Stages.

Egg (fig. 2, e).—The egg is borne on the end of a flexible stalk, the other end of which is attached to the body-wall of the scale. In shape the egg resembles a sausage,

the long axis being slightly curved. The micropylar end is a little broader than the other, but the difference is scarcely noticeable, and the sides of any longitudinal section are practically parallel. Both ends are rounded and hemispherical, and a transverse section is circular. There is a little variation in width or in the degree of longitudinal curvature. The flexible stalk is attached to the slightly broader end, and its length is about two-thirds of that of the egg. It is extremely delicate, creased and twisted, and usually is a little wider in the middle than at the ends. Its distal end adheres to the body-wall of the host very strongly, but there is no special apparatus for attachment, which must be effected simply by some adhesive substance.

The mature egg, when still inside the body of the female, bears a curious delicate appendage which explains the origin of the suspensory stalk (*cf.* fig. 2, *d*). This appendage consists of a long, delicate, transparent tube of uniform diameter which widens out at one end to form a hollow vesicle and arises from the broader end of the egg. The vesicle is shaped like a hen's egg and is closed at its free end, its length being about a third of that of the egg, and the length of the tube about half of that of the egg. The tube is curved, and its curvature is in the same direction as, but a little greater than, that of the long axis of the egg. The egg-shell and the walls of the tube and vesicle are perfectly transparent and continuous. The vesicle and the egg proper communicate with one another through the tube. The tube and vesicle are distended and contain a colourless fluid. They therefore contrast strikingly with the egg proper, which is semi-opaque at this stage, because it is completely filled with minute yolk globules. If the egg is gently pressed under a cover-glass some of the yolk passes into the appendage, which finally bursts. The egg remains in this condition right up to the time of oviposition, but immediately after oviposition, when it is inside the *Aspidiotus*, all that remains of the tube and vesicle is the flexible thread-like stalk of attachment. It is clear, therefore, that the appendage collapses at the time of oviposition.

Larva.—The newly-hatched larva is very minute, transparent and slender, and the segmentation is not very distinct. The first and second segments together form a cone with the apex flattened. The body tapers to a point at the posterior end, but the tapering is very gradual and there is little difference in width between adjacent segments except in the case of the first and second. The mouth-parts and the stomach are the only organs which can be seen at all clearly.

The full-grown larva (fig. 8), when viewed from above, is pear-shaped, the greatest width being at the fourth and fifth segments. There are fourteen well-marked segments, all of which are approximately equal in length. The mouth opens anteriorly and ventrally on the first segment. The first and last segments are button-like. The lateral and dorso-ventral aspects are quite different, on account of the marked flattening which is due to the pressure of the walls of the host on the parasite. The ventral surface is convex, and the dorsal surface is flat.

The colour of the larva by reflected light is a bright, translucent green, almost yellow, except for the first two segments which are colourless. The colour is due to the food in the gut, but the gut diffuses its colour through the fat-body which therefore appears green, though by itself it is colourless. The cuticle and body-wall are transparent and colourless, so that the alimentary canal, the tracheal system, the fat-body, and the mouth-parts, are very clearly visible by transmitted light. The fat-body is large and conspicuous; it extends continuously from the second to the last segment, occupying most of the space between the gut and the body-wall. The spiracles are lateral, rather nearer the dorsal than the ventral surface. There are usually nine pairs, one pair on each segment from the third to the eleventh, but sometimes the most posterior pair is missing. Each spiracle is situated at the front edge of its segment and is almost inter-segmental. There is one main tracheal trunk on each side and the spiracles are connected directly with it. Each of these trunks is

connected with its fellow of the opposite side by a transverse trachea dorsal to the alimentary canal in the second segment and by another in the twelfth, but otherwise they are not directly connected.

The mouth-parts are highly characteristic (fig. 3, e), consisting of a pair of pointed mandibles, always strongly chitinized, and a colourless ring which surrounds them. The ring is a thickening of the cuticle and serves as a support for the mouth-opening and as a base for the attachment of the two pairs of muscles which work the mandibles. The points of the mandibles cross one another like scissors. The form of the ring and the shape of the mandibles are constant and specific, and the fact that the mandible angle (ABC) is markedly obtuse distinguishes this larva from all other endoparasites of *Aspidiotus* in Java.



Fig. 8. *Comperiella unifasciata*, full-grown larva, as seen by transmitted light.

Pupa (fig. 9, a).—When the pupa is first formed the thorax and abdomen are translucent and of a pale yellow-green colour, rather paler than the excrement on either side. The head and the appendages bordering the thorax and abdomen are transparent and colourless. There are no surface markings and there is at first no trace of the eyes or ocelli. The pupa remains in this condition for about two days, but on the third day it is much darker and more opaque, and the eyes are very dark and distinct. Five days after pupation it is quite black and opaque all over except the wing-cases, which remain translucent.

The female pupa is subject to considerable variation in shape and colour. The variation in colour is due simply to the development of the contained adult, the pupal

skin being transparent and colourless : and therefore when two pupae are very differently coloured it is only because they are not of the same age. The variation in shape, on the other hand, depends on the distance between the dorsal and ventral walls of the host, which determines the degree of compression of the pupa, the volume of the pupa being almost the same in all individuals. As soon as the parasite larva has devoured the contents of the host completely the cuticle of the latter dries and becomes very brittle. It usually dries so that the dorsal and ventral surfaces are very close together, thus forming a thin, perfectly flat disc, and in this case the soft parasite larva, which occupies the greater part of the scale, is pushed out laterally and itself becomes very flat. By the time the larva pupates the cuticle of the host is quite rigid, and therefore the pupa also is extremely flat. Sometimes, however, the

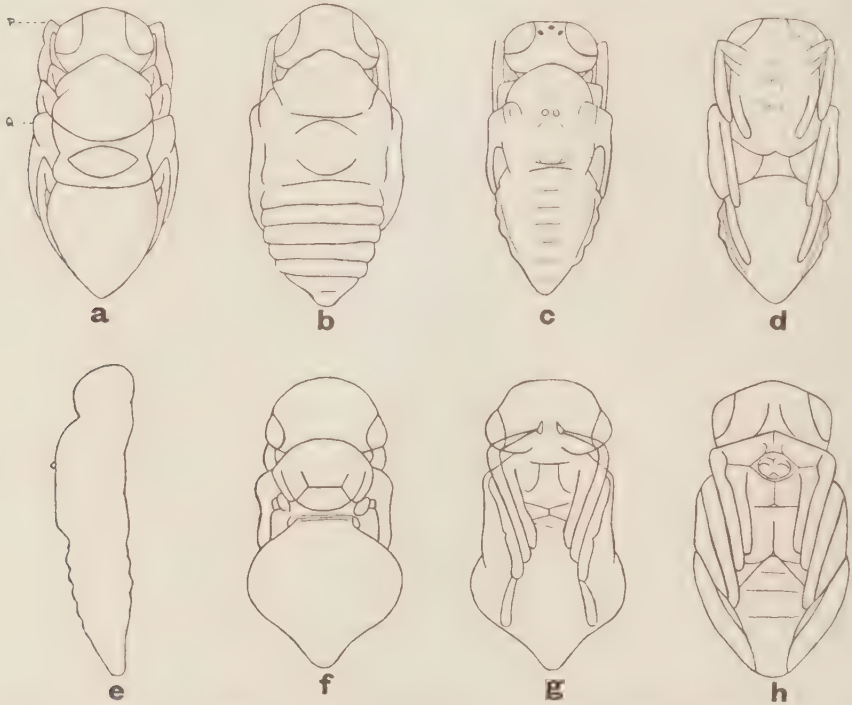


Fig. 9. Outlines of pupae of scale parasites: **a**, *Comperiella unifasciata*, dorsal; **b**, *Spaniopterus crucifer*, dorsal; **c**, **d**, **e**, *Chiloneurinus microphagus*, dorsal, ventral and lateral; **f**, **g**, *Casca parvipennis*, dorsal and ventral; **h**, *Phycus varicornis*, ventral.

Aspidiotus dries in a more or less distended condition, so that the pupa is formed without much compression, and in this case the flattening is not very marked, and the general appearance of the pupa is more like that of a more typical Chalcid. The greatly flattened form is, however, much more common than the other. The dorso-ventral compression is so great when the pupa is viewed laterally, after having been dissected out of the scale, that it looks like a thin lamina with the two surfaces parallel. As a result of the compression of the pupa during its formation the sheaths of the appendages are displaced to the sides, and the head, thorax, and abdomen form a continuous plane surface, dorsally and ventrally, practically without indentations or projections. In the other, less compressed form of the pupa the appendages are more ventral than lateral, and it is chiefly this difference which is responsible for the variation in outline of the pupa as a whole.

In spite of the difference in general appearance between the two extreme forms of the pupa, two features are absolutely constant for the species and serve to distinguish it from all the other internal parasites. These are, firstly, the manner in which the antennal sheaths project laterally on either side of the head and bend sharply at the point *p*; and secondly, the presence of a rounded projection from the anterior end of the wing-cases at *q*. There are many other specific characters, but no others can be seen clearly when the pupa is *in situ* within its host.

This description of the pupa applies only to the female. The male pupa was observed on only one occasion. It has a very different appearance from the female, chiefly on account of the position of the antennal sheaths, which are much longer than those of the female and therefore occupy a different position. In both sexes they arise near the middle of the underside of the head, and in the female their proximal portion, corresponding to the first two joints of the adult antennae, is directed towards, and projects just beyond, the side of the head at right angles to the long axis of the body, while the distal portion of the antenna is directed backwards parallel to the long axis of the body. Hence, when the female pupa is viewed dorso-ventrally the antennal sheaths appear to arise at the sides of the head. In the male, on the other hand, the proximal portions are directed forwards and project just beyond the front of the head side by side, and the distal portions proceed from them at right angles in the lateral direction and follow the curve of the head backwards, so that when the male pupa is viewed dorsally the antennae appear to arise together at the front of the head and to frame it laterally.

Despite the great difference in appearance between pupae of different sexes, the distribution and colour of the excrement, which are the same in both sexes, together with the orientation of the pupa relative to its host, serve to distinguish this species, regardless of sex, from all the others.

Life-history.

In Java *C. unifasciata* is a primary, strictly internal, parasite of *Aspidiotus destructor*. It attacks only those female scales which have passed the second moult and which are nearly or quite mature, and it is the only parasite of *A. destructor* in Java which is absolutely confined to one particular instar of the host, though all the other parasites show a marked preference for one instar. Male scales are never attacked by it.

Soon after the *Aspidiotus* has moulted for the second time, a few of the eggs within it attain their maximum size, and it is this stage that the parasite most frequently attacks. Nevertheless, the scale is liable to be attacked when it is much older than this, and occasionally even after it has laid a few of its eggs. The development of the scale ceases as soon as it is parasitised, and it is therefore prevented from laying any eggs subsequently. Cases in which the *Aspidiotus* lays a few eggs before the parasite attacks it are very rare, and as a general rule this parasite may be regarded as one which completely prevents any progeny arising from those scales which it attacks.

Egg.—The egg of *C. unifasciata* is laid in any part of the body of the *Aspidiotus* except the immediate vicinity of the pygidium, but the anterior end is usually selected. It can sometimes be seen through the transparent cuticle of the *Aspidiotus*, but is usually obscured by the body organs. It is always attached to the inside of the body-wall of the host. If a needle is applied to the pygidium and another to the anterior wall of the host, and the two are then drawn apart slowly, the host will split posteriorly in front of the opening of the oviduct and the greater part of the contents of the body, which is merely a sac of developing eggs at this stage, will be drawn out attached to the oviduct. The egg of the parasite can then be seen very clearly, because it remains attached to the body-wall inside the empty *Aspidiotus*.

Very often two or more eggs are laid in one host. In such cases all of them hatch, but all the larvae except one die when very young, and only one reaches maturity. The egg is large for the size of the adult parasite, and only a few eggs are mature in the ovary at any one time. Nevertheless the egg-capacity is considerable, because a constant succession of eggs develops for a period of at least seven days.

The development of the *Aspidiotus* ceases as soon as the egg of the parasite is inserted, and a process of disintegration sets in soon afterwards. The eggs of the host, some of which are usually large and nearly mature by this time, gradually disappear, and the whole of the body-content is eventually reduced to a fluid in which a large number of globular bodies, some bright green and some colourless, are suspended. This furnishes suitable food for the parasite larva. The disintegration gives parasitised scales a very characteristic appearance when they are viewed under the microscope by transmitted light. The duration of the egg stage is about five days.

Larva.—The larva, when newly hatched, is not easily seen within the scale on account of its small size and great transparency, but as soon as its gut becomes filled with the bright green globules in the body of the host it is fairly easy to see. The gut appears as a bright green strip amongst the variously shaped particles which are suspended in the body-fluid of the host, and though many of the particles are of the same colour as the gut of the parasite, the shape, size, and movement make the parasite obvious when the *Aspidiotus* is removed from the leaf and put on to a glass slide.

There are four larval instars altogether. At each moult the old larval skin is pushed back to the hind end of the body of the parasite, where it adheres to the last segment and also to the skin of the previous instar. Hence if the cast skins are removed from the full-grown larva and are flattened out on a slide, they are seen to contain three pairs of cast mandibles which increase in size from the most distal to the most proximal, while the functioning mandibles of the larva are the largest of all and complete the series.

The shape of the larva changes greatly during its development. So long as its thickness is less than that of its host no very noticeable changes occur, and a cross-section is nearly circular, but as soon as its thickness equals that of the *Aspidiotus* a dorso-ventral compression is brought about, since the larva has its dorsal and ventral surfaces in contact with the walls of the host.

The tracheal system is not developed until the last instar, but otherwise all the organs which can be seen in the full-grown larva are present in the young.

By the time when the larva is full-grown it has devoured every scrap of the contents of the host, and since the cuticle of the host is perfectly transparent, the parasite can be seen as clearly as if it were enclosed in a minute glass case. The process of excretion which now takes place is highly characteristic. The larva thrusts its head against the inside of the pygidium of the host, and when it is in this position its anterior end is held fast while its anal extremity touches the opposite (anterior) end of the scale-insect. Meanwhile the posterior half of the larva shrinks considerably, and on account of this the movement of the posterior half is not hindered by contact with the walls of the host, and it can be moved round inside the scale like the hands of a clock, while the anterior end remains still. The body of the larva is first bent up into the form of a U, so that the anal extremity and the head are near together at the pygidial end of the host. Excretion then commences, and as it proceeds the larva straightens out, leaving a continuous strip of excrement down the side of the scale. The operation is then repeated on the other side of the scale, beginning as before near the pygidium, and when the anal end once more reaches the anterior end of the scale excretion is complete. In this manner the scale is lined with bright yellowish-green, translucent faecal matter which is continuous, except in the neighbourhood of the pygidium and usually for a short distance at the anterior end of the scale. This

arrangement of the excrement (fig. 4, a) is absolutely constant for this species and is of great value for the recognition of the parasite in the field.

The duration of the larval stage is about $2\frac{1}{2}$ weeks on the average and is fairly constant. The shortest period recorded was fifteen days and the longest nineteen days.

Pupa.—The pupa is formed a day and a half after excretion, and is very nearly as long as the scale, excluding the pygidium, and therefore it nearly always lies in the middle line, unlike most of the other internal parasites. The head is nearly always at the pygidial end, and this is another useful feature for identifying the species in the field. Only five pupae out of many hundreds observed during a period of five months had their anterior ends at the anterior ends of their hosts. The orientation of the pupa within the scale is such that the ventral surface of the pupa is always in contact with the dorsal surface of the scale, since it is essential for the emergence of the adult that the pupa should have its back towards the leaf, the adult being so large and flattened that it cannot turn round inside the scale. The pupal stage must be regarded as terminating when the adult casts off the pupal skin within the host, although the adult does not become active until the following day or even later. The pupal period is therefore six days and appears to be constant.

Adult.—On the day following that on which the pupa turns black, the adult emerges from the pupal skin. It does not yet emerge from the host, however. All its appendages are free, and the wings are half expanded, but it remains inside the scale, keeps perfectly still, and appears dead, making no attempt to free itself from the scale. It remains like this for at least twelve hours, sometimes for two days, but sooner or later it suddenly becomes active and bites a jagged hole in the posterior half of the dorsal wall of the host and the covering scale, through which it finally emerges (fig. 4, a). The shape and position of the exit hole in the dried skin of the *Aspidiotus* are very characteristic features, sufficiently so to enable one to state, after the parasite has emerged, which species of parasite occupied the scale: though the excreta, which remain inside the scale are alone sufficient for this purpose.

The adult female is not very active. It rarely flies after it has found a batch of *Aspidiotus* suitable for the reception of its eggs. It walks leisurely over the scale on the underside of the coconut leaf, stopping at intervals to investigate individual scales with its rapidly vibrating antennae. During oviposition the head is directed away from the centre of the scale and the ovipositor is inserted near the centre. Very often the ovipositor is withdrawn again without oviposition having taken place. The parasite oviposits readily in glass tubes, and begins doing so on the day following emergence. Reproduction must nearly always be parthenogenetic. Apparently a male is liable to appear in any brood, but the great majority of broods are entirely female, and the existence of the male seems to be quite unnecessary. All the individuals reared in captivity were necessarily parthenogenetic.

The adults were never observed feeding in nature, but in captivity they feed satisfactorily on honey in water applied in very small drops to a leaf. Possibly in nature they feed on the scale-insects in the same manner as the external parasite *Aphelinus chrysomphali*, but they were never observed to do so. Females were kept alive for over two weeks occasionally, but as a rule they died within a week.

The position of the wings when at rest is very curious. For the first half of their length they lie along the abdomen, the left wing over the right, but they bend up sharply at the transverse crease near the middle so that their distal halves project upwards from a point a little in front of the tip of the abdomen at an angle of about 50 degrees to the surface on which the insect is resting. The left wing is always bent up slightly more than the right.

Nothing is known of the habits of the adult male except that the wings lie flat, one above the other, in the ordinary position.

Life-cycle.—This may be summarised as follows :—Egg stage 5 days, larval stage 16 days, pupal stage 6 days, oviposition to emergence 27 days. These figures are approximate averages, correct to the nearest day.

Natural Enemies.

C. unifasciata has no regular natural enemies, but is liable to be attacked in all its early stages by the predators of *Aspidiotus*, notably Coccinellids. There are no hyperparasites as a rule, but occasionally *Casca parvipennis* oviposits in the full-grown larva and in the pupa ; individuals so attacked are invariably killed. Attacks by these natural enemies are, however, never sufficiently frequent to diminish the efficiency of this parasite.

3. *Spaniopterus crucifer*, Gahan,

This Encyrtid is known only from Java ; it was found commonly in West and Central Java and is probably widely distributed throughout the island. It was reared only from *Aspidiotus destructor* and in captivity could not be induced to attack

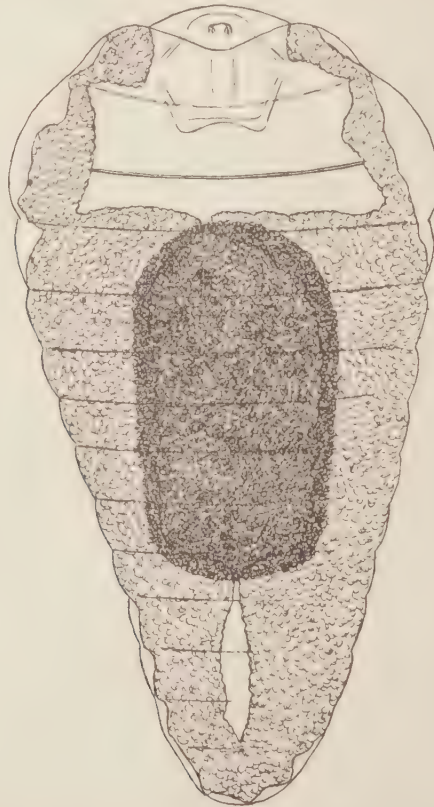


Fig. 10. *Spaniopterus crucifer*, full-grown larva as seen by transmitted light.

A. palmae or *Chrysomphalus ficus*. Hence it is probably confined to soft scales. It is never a hyperparasite. Males and females occur in approximately equal numbers in the field. In the laboratory one entirely male generation was reared from a non-mated female, indicating that this insect, unlike *Comperiella*, is arrhenotokous in the absence of males.

Description of Stages.

Egg.—The exact form of the egg after oviposition is doubtful. A large number of scales, in which females apparently oviposited, were carefully dissected, but the eggs of the parasite were never found. Mature eggs, however, were readily obtained by dissection of the ovaries. The eggs are very small as compared with those of *Comperiella*, but they resemble the latter in that each of them bears a vesicle at the end of a hollow stalk. The egg itself is ovoid in shape, and the long axis is straight.

Larva (fig. 10).—The young larva is very similar to those of *Comperiella* and was not studied in detail. The full-grown larva is readily distinguishable from all other species of internal parasites which were found in Java. It is pear-shaped, the anterior end being very broad and rounded and the remainder of the body tapering uniformly to its extremity. The greatest width is in the posterior half of the 3rd segment. This segment is very large, its length being much greater than that of any other. There are 14 segments and all are clearly marked, except as regards the dividing line between segments 2 and 3, which is indistinct. In colour and transparency the larva is the same as those of *Comperiella*. The form of the fat-body is characteristic. From segments 4 to 14 inclusive it occupies the whole of the space between the gut and the body wall, except for a small space dorsally; in front of segment 4 it extends forwards, laterally only, in the form of a narrow irregular strip as far as the anterior edge of segment 2. The tracheal system is similar to that of *Comperiella*. There are always nine pairs of spiracles. The anterior transverse commissure is very prominent in segment 3. The mandibles are strongly chitinated (fig. 3, c). The mandible angle is either right angled or slightly acute, and on the opposite side of each mandible there is a depression (x). The ring-like thickening of the cuticle which surrounds the mouth is of constant and characteristic form (fig. 3, c).

Pupa (fig. 9, b).—The cuticle of the pupa is very thin and transparent. The colouring is therefore similar to that of *Comperiella*, being due to the translucent, yellowish green body-contents. Striking colour changes occur as the adult develops and on the day prior to emergence the pupa is quite black and opaque. There are no sex differences in the pupae, but there is a great variation in shape on account of the varying degree of compression due to the walls of the scale. The pupa is smaller than that of *Comperiella* and is never so greatly flattened; moreover its outline is entirely different. It is, therefore, always easily distinguished from *Comperiella*. The most useful features in its outline for identification purposes are the backward curve of the antennal sheaths from the point at which they project from the side of the head, the shape of the head and thorax, and the particularly clear segmentation of the abdomen laterally.

Life-history.

Spaniopterus crucifer is an endoparasite of *Aspidiotus destructor*. It attacks only female scales, but is not confined, like *Comperiella*, to third-stage scales. In fact, although it attacks third-stage scales frequently, it shows a decided preference for second-stage. It never attacks scales prior to the first moult.

Egg.—The egg is laid inside the host, but has never actually been found; it is undoubtedly very small as compared with those of *Comperiella*, as dissections of the ovaries have shown.

Larva.—The effect on the host is the same as that described for *Comperiella*. The young *Spaniopterus* larvae can readily be seen inside their hosts, squirming about in the disintegrated, semi-fluid body-contents. Evidently superparasitism sometimes occurs, as three young larvae were observed in a single host, but it is unusual to find more than one. In all cases, regardless of the size of the host, only one parasite matures in each host. As in *Comperiella*, the larva, though active, can only bend itself in the lateral plane, so that it has either its dorsal or ventral surface against the wall of the host.

There appear to be only three larval instars. The cast skins, as well as the crumpled egg-shell, remain attached to the hind end of the host, and the greatest number of skins found attached to full-grown larvae was two. The tracheal system is not developed until the last larval instar.

When the larva is full-grown, its behaviour is similar to that of *Comperiella*, except as regards the distribution of its excrement and its orientation in the scale. Being smaller than that of *Comperiella*, it is not compelled to lie in the middle line when preparing to pupate. Nevertheless it almost invariably lies with its head nearer the pygidial end of the scale and its ventral aspect facing the leaf; this latter position contrasts strikingly with that taken up by *Comperiella*, which always has its back towards the leaf. The excrement (fig. 4, c) is deposited on both sides of the scale but never extends the length of each side. It is confined on each side to a short narrow patch, and is much less conspicuous than that of *Comperiella*. The two patches are opposite one another and closely apposed to the sides of the host. Their colour is dark brown and they are almost opaque.

Pupa.—The pupa is formed on the day following that on which the larva excreted, and it turns black 4 days later. The duration of the pupal stage is 6–7 days.

Adult.—The adult's development within the pupa is very readily observed through the scale. When it casts off the pupal skin it does not at once emerge from the host but remains motionless inside for usually at least 12 hours. During this time it rests as a rule facing the leaf, but at the end of this period it turns over and begins to bite its emergence hole in the upper wall of the scale near the pygidium, though not necessarily in the middle line. The hole is smaller than that of *Comperiella* and differs also in that its outline is much less jagged (fig. 4, c).

The adults are not very active, and are very similar in habits to *Comperiella*, except that copulation is the rule and apparently occurs on the day on which the female emerges from its host. Oviposition begins the same day. Both sexes were kept alive for 7 days when fed on diluted honey. The sexes, though similar, are readily distinguished in the field on account of the fact that the male, when at rest, always holds its antennae curving backwards and never extending in front of the head, while those of the female extend forwards and outwards.

Life-cycle.—This was not worked out in detail except for the total period from oviposition to emergence of the adult. This proved to be 24 days in Java. The pupal stage was observed for 6 individuals and averaged $6\frac{1}{2}$ days.

4. *Chiloneurinus microphagus*, Mayr.

Range.

This Encyrtid has a very wide distribution, being recorded from Spain, Russia and Java. The host recorded in Spain is *Diaspis rosae*, and in Russia, *Aspidiotus ostreaceiformis*. In Java, both *Chrysomphalus ficus pallens* and *Aspidiotus destructor* were commonly attacked.

Both sexes are common, but females predominate as a rule, although one batch of 23 pupae collected in the field produced all males. This suggests that parthenogenesis occasionally occurs in nature.

Description of Stages.

The egg and early larval stages of this parasite were not studied.

Full-grown larva.—In general appearance the larva resembles those of *Physcus*, *Casca*, and *Aspidiotiphagus* on account of the fact that it is permanently curved in the dorso-ventral plane. In shape it is identical with *Physcus*. It is, however, readily distinguishable from these other species by certain anatomical features, of which the most useful for the purpose of identification in its host is the form of the fat-body.

The ventral portion of the fat-body is not detached as in *A. citrinus* and *C. parvipennis*; and there are no dark patches as in young *P. varicornis*, and no darkening of the ventral portion of the fat-body as in full-grown *P. varicornis*. There are 14 segments and the segmentation is distinct. The mandibles are similar to those of *P. varicornis*, but are not so strongly chitinised, and the points are straighter. The tracheal system is very well developed, the tracheae being unusually thick and prominent. There are 9 pairs of spiracles, situated on segments 3-11 inclusive. The spiracles are of a peculiar form, not found in any of the other species investigated. When the larva is viewed from the side, each spiracle has the appearance of two concentric circles, but when viewed dorso-ventrally, it is seen to consist of two trumpet-like structures, of which the smaller fits inside the other.

Pupa (fig. 9, c, d, e).—The pupal skin is transparent, and the pupa is exceptionally shiny and smooth, particularly when it turns black prior to the emergence of the adult. It is flat ventrally, convex dorsally, and somewhat flattened, but much less so than that of *Comperiella*. In outline the pupa resembles *Comperiella* but can at once be distinguished by the serrated edge of the abdomen, which is due to the marked segmentation. Another useful feature is the presence of a pair of minute prominences in the centre of the thorax dorsally. There is a marked sexual dimorphism in the pupa, comparable in nearly every respect with that found in *Comperiella*, notably as regards the manner in which the antennal sheaths project from the head.

Life-history.

C. microphagus is an internal primary parasite of *A. destructor* and *C. ficus*. It was found attacking 3rd stage female scales only. The life-history was not studied in detail, attention being paid only to those features which serve for identification.

Larva.—The larva lies on its side in the scale, this habit being associated, as is always the case, with the permanent curvature of the body in the dorso-ventral plane. When ready to pupate it distributes its excrement all down either side of the scale in the same manner as *Comperiella*, but the excrement differs from that of the latter in being darker, more opaque, and more bulky.

Pupa.—The pupa does not occupy so much of the space in the host as that of *Comperiella* and its orientation within the scale is very variable. The only feature in this connection which was found to be constant is that the pupa has its ventral surface facing the leaf. The pupal cuticle is very thin and transparent and the pupa is therefore of a translucent yellow-green colour until two days before the adult emerges, when it becomes black.

Adult.—The adult remains inside the host for about 12 hours before liberating itself. Its exit-hole has a very jagged outline, and in this respect it resembles that of *Comperiella*, but its position varies greatly, according to the position of the pupa. The female, when alive on a leaf, is similar to *Physcus varicornis* but may be distinguished from it by the position of the antennae, when the insect is at rest; these are directed backwards, downwards, and outwards, while those of *P. varicornis* are directed forwards and upwards, side by side.

5. *Casca parvipennis*, Gahan.

This Aphelinid is at present known only from Java. It has probably been overlooked elsewhere on account of its great similarity in general appearance and habits to *Aspidiotiphagus citrinus* and its close association with that insect.

C. parvipennis was reared in Java as a primary parasite of *Aspidiotus destructor*, *A. palmae* and *Chrysomphalus ficus pallens*. As a secondary parasite it was found to attack several of the primary internal parasites of *Aspidiotus*, including *Comperiella*, *Aspidiotiphagus*, *Spaniopterus* and *Physcus*. It was also reared as a secondary parasite from pupae of its own species which were primary parasites in *A. destructor*.

Both sexes are common in Java, but females predominate. It was noticed also that the two sexes rarely occur together in the same batch of scales, but that each batch produces, as a rule, either all females or all males. This implies that parthenogenesis frequently occurs in nature in this species. It was further observed that whenever the food supply of the larvae of this parasite is limited, whether as a result of superparasitism or of the host individuals being small or of the fact that the host was one of the other scale-parasites instead of the scale itself, the resulting adults were male. All individuals reared as secondary parasites were males, and the great majority of those reared from male scales, and from female scales in the early second instar, were also males. All those reared from full-grown female scales proved, without exception, to be females. Scales which were in the late second instar produced both males and females. We are, however, not prepared to state that the smallest host individuals produce male parasites invariably. It is noteworthy that a similar phenomenon was observed in *Physcus varicornis*.

Description of Stages.

Egg (fig. 2, b).—The shape of the egg is unusual and characteristic, resembling that of a somewhat elongated lemon. One end is rather more pointed than the other, and one side is slightly flattened. The greatest width is a little nearer the blunter end and is equal to half the length. There is no appendage. Dissection of mature females shows that there is no vesicle attached to the egg at any stage in its development. The egg is perfectly transparent and colourless.

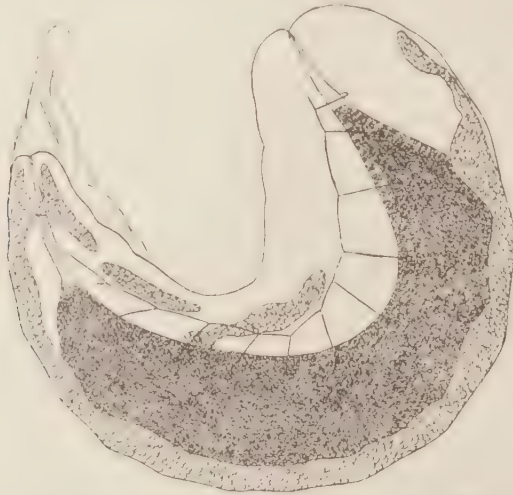


Fig. 11. *Casca parvipennis*, full-grown larva as seen by transmitted light, showing, in particular, the gap in the chain of spiracles.

Larva.—The young larva in the first instar is elongated and very transparent, and only the gut can be seen clearly. The segmentation is indistinct but is more apparent at this stage than in older larvae. The egg-shell usually remains attached to the terminal segment, forming a short tail. The larva is almost straight in the first instar, but in the second instar it acquires a permanent, though slight, curvature in the dorso-ventral plane, the ventral surface being on the inside of the curve. It is now much less transparent and the fat-body is clearly seen. From this stage onwards the body tapers regularly from the fourth segment, which is the widest, to the anal extremity. At each moult the cast skins usually remain attached to the anal end of the larva, which therefore appears to be wrapped posteriorly in a very delicate membrane.

The full-grown larva (fig. 11) is thick-set and somewhat flattened laterally. The curvature is now very great, and the larva is incapable of straightening itself out. The longitudinal axis forms rather more than a semi-circle. The segmentation is very indistinct. Most of the body organs are easily seen on account of the great transparency of the body-wall. The stomach occupies the greater part of all the segments from the 3rd to the 11th inclusive. The contained food makes it opaque and conspicuous, but the oesophagus and rectum are transparent and difficult to see. The space between the gut and the body-wall is occupied dorsally and subdorsally by the fat-body, which extends forward, dorsally only, into the 2nd segment as a narrow strip; it also extends backwards dorsally to the posterior extremity. In the last segment it encircles the rectum at a point a short distance in front of the anus. The encircling ring connects the dorsal portion with a narrow ventral strip which lies in the last two segments. In the centre of the body, on the ventral side of the gut, there is a long strip of fat-body which usually extends from segments 6 to 10 inclusive; and between this and the ventral terminal strip there is another elongated portion which is quite separate from the others.

The tracheal system does not appear until the last instar. It is liable to considerable variation, but in its most usual form it is very characteristic as compared with those of the other parasites of *Aspidiotus* in Java. There are 9 spiracular tracheae on either side connected with the main lateral trunk, but only 8 of these terminate in spiracles, there being no spiracles on the 5th segment, although the spiracular tracheae therein are well developed. The 8 pairs of spiracles are therefore situated on segments 3 to 11 inclusive, with the exception of segment 5. This peculiar arrangement is undoubtedly the usual one for this species, but it is by no means constant. Occasionally the last pair of spiracles is absent, and frequently the third pair, which is missing in the majority of specimens, is present, making 9 pairs in all.

The mouth-parts (fig. 3, **b**) are subject to great variation, chiefly as regards their degree of chitination and, therefore, their distinctness of outline. In full-grown larvae which are attacking mature scales the mouth-parts are always distinct and constant in form, but in larvae which are attacking younger scales or which are secondary parasites the mouth-parts are very little chitinated and vary in form. The most important features are the shape of the mandibles and the absence of any transverse thickening completing the oral ring ventrally.

Pupa (figs. 9, **f**, **g**; 12).—The pupa varies greatly in shape according to the shape of its host. Female scales in the 2nd stage are relatively elongate as compared with those in the third, and pupae of this parasite in 2nd stage scales are correspondingly elongate, while those in 3rd stage scales are broad and squat. Since the pupa occupies almost the whole length of the scale in either case and its bulk, relative to that of the host, is constant, its shape must conform to this extent to that of the host. This variation is illustrated in fig. 12. In addition, there is much variation in the shape of the head. A pupa with its head towards the pygidium of the host is subject to considerable pressure anteriorly, which has the effect of pushing the sides of the head backwards (fig. 12, **a**). A pupa with its head at the other end is not subjected to the same pressure and its head is of more normal shape (fig. 12, **b**).

The shape of the pupa also varies strikingly according to its sex. The male pupa is much slimmer than the female, and the abdomen is no wider than the thorax. In the female the abdomen is usually considerably wider than the thorax. The very broad form of pupa shown in fig. 12, **a**, is characteristic of all female individuals attacking mature female scales. Female pupae in 2nd stage scales, being more elongate, are less readily distinguishable from the males.

The newly-formed pupa is translucent, almost transparent, and pale green or yellow throughout. Small pupae, particularly those which are secondary parasites,

are almost colourless. The eyes become red and opaque after about two days and on the following day they are black. At the same time the abdomen develops six transverse, dark brown, segmental bands which make the pupa conspicuous as a black dot, visible to the naked eye, when a batch of parasitised scales is held up to the light. The rest of the body acquires a darker yellow colour as development proceeds, but remains translucent throughout the pupal stage. The colour and markings of partly or fully developed pupae are very characteristic and make this species readily distinguishable from all the others studied in this connection, except *Aspidiotiphagus citrinus*.

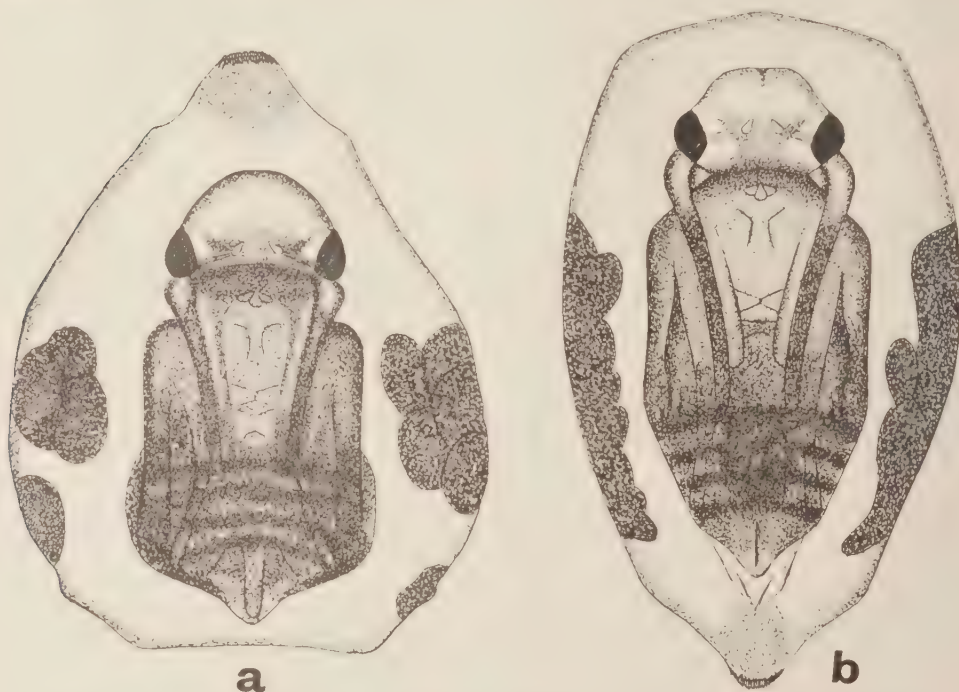


Fig. 12. *Casca parvipennis*, pupae in situ in *Aspidiotus destructor*, as seen by transmitted light. **a**, in full-grown scale-insect; **b**, in smaller scale-insect.

Life-history.

C. parvipennis is a primary, internal parasite of *Aspidiotus destructor*. It was occasionally reared from *A. palmarum* and *Chrysomphalus ficus pallens*, but shows a very marked preference for *A. destructor*. In this respect it differs from the otherwise similar insect, *Aspidiotiphagus citrinus* var. *agilior*, which prefers *C. ficus pallens* and *A. palmarum*. Although typically a primary parasite, it is very frequently a hyper-parasite, attacking the prepupae and pupae of any of the primary internal parasites, including individuals of its own species.

The age of the scales selected varies greatly: 1st stage scales are never attacked, but both 2nd and 3rd stages are commonly attacked, the late 2nd being preferred, apparently. Male scales are occasionally parasitised by this insect. Individuals in young 2nd stage scales very frequently fail to mature, and a very high percentage of those which are secondary parasites die similarly without pupating. This indicates that *C. parvipennis* is essentially a parasite of the larger scale individuals, and that the food supply available in small scales and primary parasites is insufficient for its needs.

Egg.—The egg is not attached in any way to the host, but is freely suspended in the body fluid. The duration of the egg stage is about three days. On one occasion, three eggs were found in one scale, but this is probably unusual. In any case, only one individual matures in each host, even when the host is a large 3rd stage scale.

Larva.—There appear to be only three larval instars, since the number of sets of mandibles found in the cast skins of the full-grown larvae never exceeded two.

The position taken up by the larva, when it has devoured all the contents of the host and is ready to pupate, varies according to the stage of the host but is fairly constant for each stage. Thus, larvae in 2nd stage scales usually lie with their hind extremities at the pygidial ends of their hosts, while those in 3rd stage scales take up the reverse position. This difference is no doubt due to the difference in shape of 2nd and 3rd stage scales. In all cases the larva has its back in contact with the ventral wall of the host. During the feeding period the larva is permanently curved in the dorso-ventral plane and is therefore compelled to lie on its side in the scale, and the process of turning on to its back when fully fed is only possible by the considerable amount of contraction which it undergoes preparatory to pupating.

Having taken up its position for pupation, the larva then excretes, in a manner very similar to that already described for *Comperiella*. The distribution and colour of the excrement (figs. 4, b: 12) are important factors in identifying the insect at this stage. The excrement is deposited in two patches, one on either side of the scale; each patch is short as compared with that of *Comperiella*, and bulky as compared with that of *Spaniopterus*. The colour of the excrement by reflected light is rich yellow or yellow-green, but being nearly opaque the excrement is dark brown by transmitted light. The colour by reflected light is the same as that of *Comperiella*, but since the latter is transparent its colour is nearly the same by transmitted light.

Pupa.—The larva pupates on the day following that on which it excretes. The colour changes of the pupa, already described, are very noticeable, and cause newly-formed pupae to look quite different from older ones, but the orientation of the pupa and the excrement simplify the recognition of this species.

When this insect is a secondary parasite its larva always emerges, partly or wholly, from its host to pupate. Since the host is a prepupa or pupa of *Comperiella* or one of the other primaries, which is itself entirely enclosed by the dried, glassy cuticle of the scale-insect, the secondary parasite on leaving its host is enclosed by the scale cuticle only, just as it would be if it were a primary. The empty and extremely delicate cuticle of the primary is usually invisible, and, therefore, when the secondary pupates it might readily be mistaken at first for a primary. Secondary pupae are, however, easily recognized as such by their much smaller size and by the presence of two sets of excrement—their own and that of their host. A secondary pupa may lie in any position in regard to the scale cuticle in which it is enclosed, and is very small compared with the scale; a primary pupa lies in a definite position as a rule, occupies the greater part of the scale, and is comparable in size to it. The excrement of the secondary pupa usually lies on either side of it but is not in contact with the walls of the scale; it is therefore seen as two patches, distinct from those of the primary in the same scale, and much smaller. The duration of the pupal stage is 5–6 days.

Adult.—The adult rests within the host for a few hours after emerging from the pupa, but always emerges from the host on the same day as from the pupa. When the parasite is primary, the emergence hole in the scale is at the pygidial end in 3rd stage scales and at the other end in 2nd stage scales, according to the position of the pupa. When the parasite is secondary, the hole may be in any position, and is much smaller than that of a primary individual. The outline of the hole is always fairly smooth and regular, and is readily distinguished from that of any of the other internal parasites except *A. citrinus*.

Oviposition commences on the day after the adult emerges. The adult is very thorough when ovipositing, working over the first batch of scales it finds and scarcely missing any, so that parasitism by this species often amounts to at least 90 per cent. in small batches of scale. It is unusual to find only a few scales here and there attacked. Apparently the adult never moves far from the leaflet on which it emerged unless forced to do so by lack of scales. Small scales, including males, are attacked in quantity only when no larger ones are available.

Males all died within 24 hours in captivity when fed on dilute honey. Females lived for about 5 days in the same circumstances.

Life-cycle.—This was not worked out accurately but covers approximately 2½ weeks from oviposition to emergence.

6. *Aspidiotiphagus citrinus*, Craw var. *agilior*, Berl.

This Aphelinid is of almost world-wide distribution. It has been found in several European countries and also in North and South America, the West Indies, the East Indies, Africa, India, and in nearly all of the main groups of Pacific Islands. Moreover, its distribution in each country or group of islands appears to be very general.

It attacks a great variety of scale-insects, including species from the following genera:—*Aspidiotus*, *Chrysomphalus*, *Lepidosaphes*, *Chionaspis*, *Hemichionaspis*, *Pinnaspis*, *Diaspis*, *Coccus*, *Aulacaspis*, and *Fagisuga*. The variety *agilior*, Berl., was reared in Java from *Chrysomphalus ficus pallens*, *Aspidiotus palmae*, and *A. destructor*.

Both sexes are plentiful in Java and in Fiji.

Description of Stages.

Egg.—The shape of the egg is elliptical and elongate, and the long axis is very slightly curved. The micropylar end tapers almost to a point, which is sometimes directed outwards in the direction of the long axis of the egg, but is often recurved. The egg bears neither a vesicle nor a stalk.

Larva.—The larva is permanently curved in the dorso-ventral plane, and therefore always lies on its side in the scale. It is very similar in every respect to that of *Casca parvipennis*, and no absolutely certain means of distinguishing these two species without the aid of a microscope were found. The description of the full-grown larva of *C. parvipennis* applies in every particular to the present species also, except as regards the peculiarities noted in the tracheal system. In *A. citrinus* there is always a complete chain of spiracles, the usual pair on segment 5 being present. There is, however, some variation in the number of spiracles. The typical number is 9 pairs (on segments 3–11), but occasionally the last pair is missing.

Pupa.—The pupa is extremely similar to that of *C. parvipennis*, already described, and it was found impossible to distinguish it with certainty except when the adult was about to emerge. The transparent cuticle renders the contained adult readily visible and the characteristic antennal features are apparent. It should, however, be noted that the extremely broad form of pupa figured for *C. parvipennis* does not occur in this species.

Life-history.

This insect is a primary internal parasite of *C. ficus pallens*, *A. palmae* and *A. destructor*. In Java, it attacks the two former much more commonly than the last, and in this respect differs from *C. parvipennis* which also attacks all three species.

Scales of any age, except those in the 1st stage, are attacked, and males are attacked as commonly as females. A preference is shown for young 2nd stage females, and males. Secondary parasitism by this insect was never observed, but probably occurs occasionally. Superparasitism is common, particularly with *C. ficus pallens*.

as host. Frequently as many as 5 individuals mature in one scale. Nevertheless, superparasitism is not the normal habit of this parasite, and the great majority of scales contain only one individual.

The habits of the early stages are identical with those of *C. parvipennis* in most respects. Unfortunately no opportunity arose for studying this insect in great detail. In connection with superparasitism it is interesting to note that each larva when preparing to pupate becomes separated from its neighbour on either side by a delicate transparent septum, which extends right across the scale; the scale is thus divided up into a number of small "cubicles." Each larva deposits its excrement against the sides of its own cubicle. The mode of formation of the septa is not clear. When the adult parasites emerge, each makes a separate hole through the cuticle of the host and through the covering scale, the septa remaining intact even after all the parasites have emerged.

7. *Physcus varicornis*, How. var. *intermedia*, Gahan.

The typical form of this Aphelinid is recorded from North America, and the variety *intermedia* from Java. In America *P. varicornis* attacks the San José Scale, *Aspidiotus perniciosus*. The var. *intermedia* was reared in Java chiefly from *Chrysomphalus ficus pallens*. It appeared never to attack *Aspidiotus palmarum*, and to attack *A. destructor* very rarely and only when the latter scale was closely associated with *C. ficus pallens* on the same leaflet. Females were found to predominate but males were nevertheless common.

Description of Stages.

Egg (fig. 2, c).—The general shape of the egg is similar to that of *Comperiella unifasciata*, to which it is also approximately equal in size. It is of an elongate ovoid form, but is not quite symmetrical about the long axis, except when viewed dorso-ventrally, on account of a slight longitudinal curvature. Its greatest width is at about a quarter of its length from the anterior end. Fig. 2, c, shows the shape of a median longitudinal section, which is constant and specific. The portion *p-q* of such a section is almost a straight line, while the opposite edge *r-s* is concave. The features are important in identifying the egg, which has no appendage and is not stalked.

Larva (fig. 13).—The young larva in the first instars is long, slim, circular in cross-section, very transparent, and clearly segmented. There are 14 segments, and all of them are comparable in length, though 2, 3, 13 and 14 are usually a little longer than the remainder. The width of the body is uniform as far as the middle, and the posterior half tapers regularly to the bluntly pointed anal extremity. The first segment is rounded, but is otherwise more or less conical. The body is permanently curved like a new moon, and the ventral surface is always on the inside of the curve. The internal organs are very apparent. The organs in the first two segments are perfectly transparent, except the mouth-parts, and are therefore almost invisible. The stomach extends from the third segment to the twelfth, and is made very obvious as a broad green strip by the contained food. The two most striking and characteristic features of the first instar larva are the presence of a rudimentary tracheal system and of two dark patches, which are black and opaque by transmitted light, near the posterior end.

The tracheal system is represented on either side by a single, long, extremely fine thread, which is silvery by reflected light and black by transmitted light, and which is the rudiment of the lateral tracheal trunk of the full-grown larva. At this stage it has no branches and is not connected with its fellow of the other side; nor is there any trace of the spiracles. It extends from the second segment to the twelfth. The existence of these rudiments at such an early stage is remarkable. In all the other species of internal scale parasites examined in Java the tracheal system does not appear until the last larval instar. The feeding habits of this species appear to be

identical with those of the others, and the larva is constantly surrounded, except when it is ready to pupate, by the fluid contents of the body of the host. In this species, as in the others, the spiracles are not formed until the last instar, and it is therefore

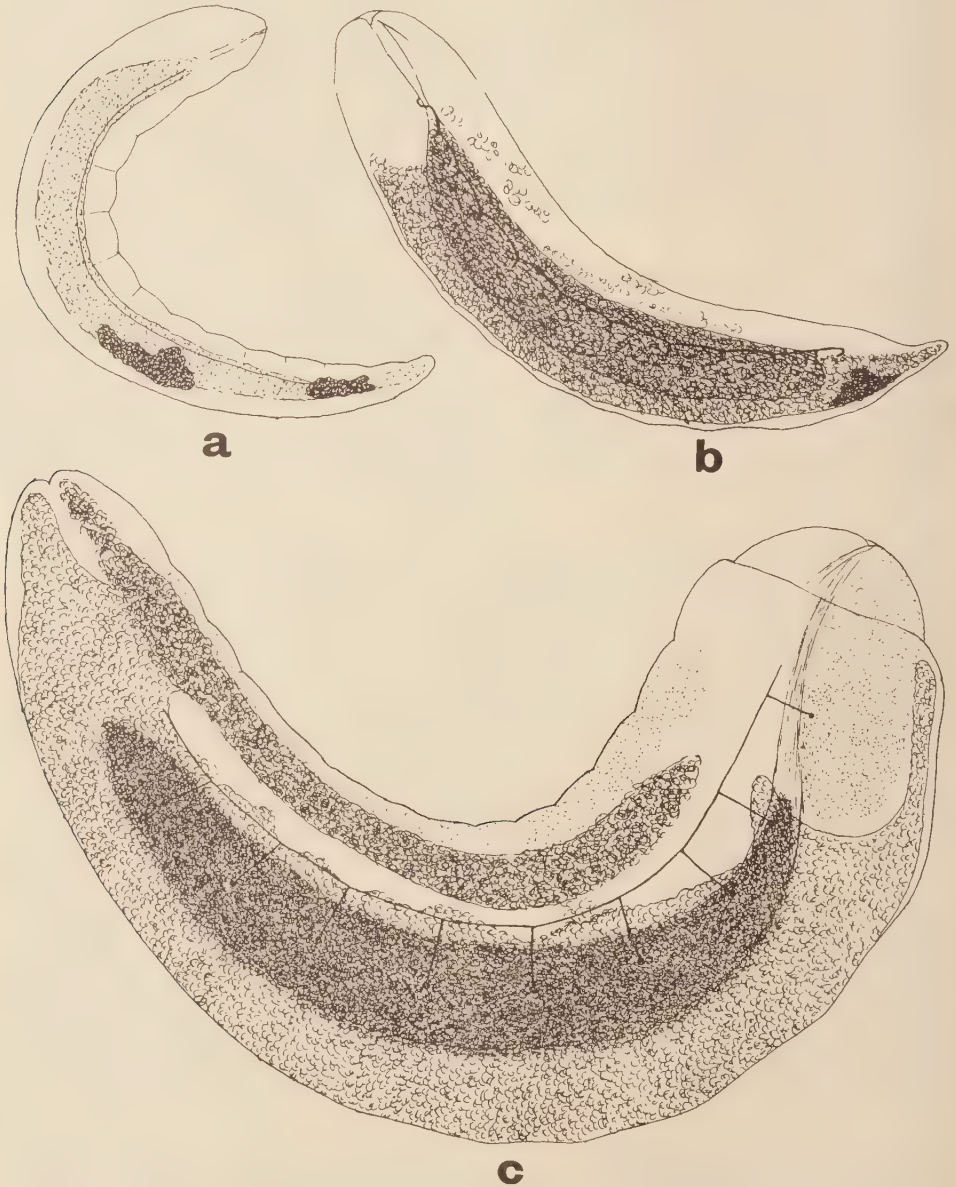


Fig 13. *Physcus varicornis* var. *intermedia* : **a**, 1st instar larva ; **b**, 2nd instar larva ; **c**, full-grown larva ; (all as seen by transmitted light).

the more remarkable to find the rest of the tracheal system developing so long before it can become functional. By the time the larva is half-grown all the main tracheal vessels are formed, including the anterior and posterior transverse vessels and those

which will connect the spiracles with the lateral trunks. The transverse vessels are in the second and twelfth segments respectively. In spite of this comparatively extensive internal development, respiration at this stage must be effected, as in the other species, solely by an osmotic process through the extremely thin cuticle.

The two black masses already referred to are very prominent and characteristic in the first instar larva. Their positions are approximately constant in all individuals, though their shape is variable. The more anterior of them usually lies in the eighth and ninth segments and is outside the gut on its dorsal side. The posterior mass is at the hind end and the greater part of it lies in the thirteenth segment, and is dorsal to the gut. The masses consist of a large number of dark globules very closely packed together. Their origin and function are obscure, and there is nothing corresponding to them in the other species. They gradually disappear as the larva grows; by the time it is half-grown the anterior mass has disappeared, but the posterior one persists longer.

In the full-grown larva the first three segments are almost colourless, except for a dorsal extension of the fat-body, but all the remaining segments are darkened by the stomach and the fat-body. The segmentation, unlike that of the first instar larva, is very indistinct. The stomach is very prominent, and the space between it and the dorsal and lateral parts of the body-wall, from the fourth segment to the anal extremity, is occupied almost entirely by the fat-body. Ventrally the fat-body is not so extensive, being in the form of a long continuous strip which passes through all the segments from the fourth to the fourteenth inclusive and lying between the ventral chain of ganglia and the gut, but between it and the gut is a narrow clear space. This part of the fat-body is separate from the remainder except at about the thirteenth segment, where it merges with the dorso-lateral portion behind the end of the stomach. In the earlier stages the ventral portion is represented only by a few scattered groups of globules. The fat-body extends forwards, dorsally only, into the third and second segments. This extension is very narrow and sharply outlined, and is bounded dorsally by the body-wall and on its ventral side by the cerebral nerve mass. The ventral portion of the fat-body is darker than the remainder.

The nervous system can be seen much more clearly in this larva than in any of the others examined. The cerebral nerve mass occupies nearly the whole of the dorsal half of the first three segments. The ventral chain of ganglia begins in the third segment, the pair in that segment being very prominent, and it extends to the anal segment, becoming much less apparent posteriorly because the ventral portion of the fat-body obscures it.

The oesophagus is very narrow and only faintly visible. The stomach is dark greenish-brown in colour on account of the contained food.

The mouth-parts are as characteristic in this species as in the others (fig. 3, d). In the early instars the shape of the mandibles cannot be made out clearly, although there is always considerable chitinisation in their immediate neighbourhood, but in the last instar they are very clearly defined and constant in form. There is the usual transparent thickening of the cuticle round the mouth, and this is clearly defined in all instars, but is liable to considerable variation in form ventrally. Dorsally, it consists of a semi-circular strip bordering and supporting the mouth. Each end of the semi-circle is continued ventrally into a long arm, which forks at its ventral extremity. The two prongs of the fork are very short in the full-grown larva, and their form and relative positions are specific characters. There is frequently an indistinct linear transverse thickening joining the two inner prongs, but this is subject to considerable variation in shape and degree of development, and is often entirely absent. Just below the mandibles there is a curved row of six minute lens-like spots, three on either side. The middle pair is larger than the others.

The lateral tracheal trunks are very distinct. There are nine pairs of spiracles, one pair each in segments 3 to 11.

Pupa (fig. 9, h).—The pupa is very obiect and plump. Its length is nearly twice its width. The ventral surface, into which the appendages are inseparably incorporated, is flat, and the dorsal surface is strongly convex. The posterior extremity is rounded. The wing-sheaths extend to the end of the abdomen and are folded on its ventral surface. The surface is minutely reticulated, except on the leg-sheaths, the eyes, and the ventral surface of the thorax. It is entirely without markings, and is usually black all over, but sometimes the ventral surface is dark brown. There are no sex differences.

The pupa turns black on the same day as it is formed, and the pupal skin is strongly chitinated, opaque, and comparatively thick. The pupae of all the other internal parasites of *Aspidiotus* and *Chrysomphalus* observed in Java do not turn black until one day before the adult emerges, and the cuticle is extremely thin, the colour of the pupa being due, not to the skin, as in the present species, but to its contents.

Since *Chrysomphalus ficus*, the normal host of this parasite in Java, is a comparatively thick scale, the contained pupa is not specially flattened. The walls of the normal host do not exert any appreciable pressure, but in those rare instances when the host is *A. destructor* a considerable flattening is noticeable and the outline of the pupa is quite different.

Life-history.

Physcus varicornis var. *intermedia* is a primary internal parasite of *Chrysomphalus ficus*, and very occasionally attacks *Aspidiotus destructor*. It attacks female scales only, and was only reared from mature scales; its attack is almost invariably early enough to prevent its host from laying any eggs. A remarkable habit of this insect is that it is cannibalistic in a special sense. It parasitises prepupae and pupae of its own species very frequently, but appears never to attack the other internal parasites.

The early stages of this parasite are very interesting when compared with those of the other parasites of *Chrysomphalus* and *Aspidiotus* in Java, for although in general its life-history is very similar, in certain features it differs widely from them. In the larval and pupal stages, therefore, this is the most easily recognised of all the parasites of the three common coconut scales in Java.

Egg.—Very frequently two or more eggs are laid in one host. In such cases all the eggs hatch but all the larvae except one die young. The duration of the egg stage is not known.

Larva.—The larva is permanently curved in the dorso-ventral plane and therefore lies on its side in the scale. It is very active and wriggles constantly, but is incapable of straightening itself out completely.

It changes very little in shape as it grows except that it becomes a little stouter. No appreciable flattening occurs, except in those rare specimens whose hosts are *Aspidiotus destructor*. The dorso-ventral thickness of its normal host, *Chrysomphalus ficus*, is much greater than that of *A. destructor*.

There are only three larval instars. The cast skins sometimes adhere to the hind end of the larva and are dragged about in the host by it, but more often they become detached.

When the larva is ready to pupate it has devoured all the contents of the host, and the cuticle, which is all that remains of the host, is of glassy transparency. The larva then excretes and becomes a prepupa. The excrement (fig. 4, e), which is dark brown and translucent, is deposited in two compact heaps, one on either side of the prepupa. The larva pupates on the day following excretion, and the pupa turns black within a few hours.

Pupa.—The pupa always lies with its ventral side in contact with the ventral wall of its host, but otherwise its orientation does not show the same constancy as do those

of the parasites of *A. destructor*. It may lie in any direction relative to the host, presumably because the thickness of its host is sufficient for it to do so without undue compression in any plane. The duration of the pupal stage is 8 days.

Adult.—The adult emerges from the scale soon after it has emerged from the pupa, instead of remaining inactive for some time within the host like most of the other species. The adult effects its exit by biting a hole in the dorsal scale-covering, the hole (fig. 4, e) being nearly half way between its apex and periphery, and smaller and more regular than that of *Comperiella*. The old pupal skin, which is black and opaque, is very conspicuous inside the host after the adult has emerged, and when examined under the microscope it has a characteristic dotted appearance which is due to minute pits. In all the other internal scale parasites studied in Java the pupal skin is so thin and delicate that it shrivels almost to nothing when the adult emerges and is often impossible to detect.

Life-cycle. No accurate determination of the duration of the egg and larval stages was made, but the pupal stage was found to be constant at eight days, and observations made in the field show that the total duration of the life-cycle from oviposition to emergence is approximately one month.

Life-history of P. varicornis as a Parasite of its own Species.

Reference has already been made to this insect's strange habit of parasitising individuals of its own species. There is no doubt that it is normally a primary parasite, and in view of the fact that several hundreds of scales containing larvae and pupae of other parasites were carefully examined without *P. varicornis* ever being found inside the other species, there seems little doubt that it is not a secondary parasite in the ordinary sense of the term. For whereas some scale parasites seem unable to distinguish between healthy scales and those which contain parasites, and therefore occasionally become secondary parasites by ovipositing in the contained larvae or pupae, this insect appears deliberately to attack scales which contain larvae or pupae of its own kind and to discriminate between these and others.

The eggs are laid in full grown larvae, prepupae and pupae *in situ* in their hosts, the ovipositor being thrust through both the cuticle of the scale-insect and that of the contained parasite. The development of the primary parasite ceases soon afterwards.

A curious feature in the history of this insect as a hyperparasite is that the larva always emerges from its host two or three days before it is ready to pupate, whether the host be in the larval or pupal stage. When the same insect is a primary parasite with the scale as host it never emerges until it becomes adult. The secondary parasite's host is a larva or pupa of its own species and therefore, on leaving its host, it finds itself inside the scale insect which has already been emptied. It then proceeds to feed upon the remains of the primary, and for this short period it is an external parasite, although inside the scale. When the primary is a larva, it is completely devoured, and not even the cuticle remains. • When it is a pupa the old black skin remains (fig. 4, f). The excrement of the primary parasite is never devoured, but remains in its normal position. The secondary larva excretes in a similar manner, but being much smaller than the primary its two patches of excrement are also much smaller, though they are distributed in a similar manner. But the secondary, on account of its smaller size, is unable to reach both sides of the scale, so that while one of the patches of excrement is at the side of the scale the other is usually against the old pupal skin of the primary (fig. 4, f). The recognition of pupae of this insect as secondary parasites is thus a simple matter on account of the presence of two lots of excrement. The secondary pupa is much smaller than the average primary pupa, so is the adult and the exit-hole.

It is very remarkable that although females are normally more numerous than males, all the 30 individuals reared as secondary parasites on their own kind proved to

be males. Parthenogenesis can scarcely have been the cause, since it is abnormal in this species, and the 30 individuals, collected in the field, were from two widely separated localities (Pekalongan and near Buitenzorg). Two other explanations suggest themselves; firstly, the limitation of the food-supply may result in the production of males only; and secondly, males may result from individuals which have fed upon their own species. This latter explanation, unlikely as it is on ontogenetic grounds, is supported by the fact that out of a great many individuals reared as primary parasites not a single male occurred; and although males were found commonly in the breeding jars containing parasitised scale in the field, all of them were very small as compared with the females, and were, in fact, of approximately the same size as those which were definitely known to be secondaries. Unfortunately, it was impossible at the time to study this phenomenon in detail, and therefore no definite conclusions could be drawn.

Natural Enemies.

No parasites were found attacking this insect. Several predators devour the larvae and pupae, notably Coccinellids and *Aleurodothrips*.

8. An Encyrtid, genus near *Thomsoniella*.

Found abundantly in Central and West Java.

Aspidiotus destructor was the only one of the three scales studied in Java to be attacked by this insect. Like *Spaniopterus crucifer*, it appears never to attack hard scales.

The sexes appeared to occur in approximately equal numbers, and males were present in every batch of scale attacked by this insect.

Life-history.

This species is a primary internal parasite of *Aspidiotus destructor*. It never attacks male scales, and is most commonly found in 2nd stage females, though it also attacks females which have already undergone the 2nd moult.

Its habits are absolutely identical with those of *S. crucifer*, and the account of the habits of the latter applies in every respect to this insect also. Larvae and pupae reared from eggs laid in the laboratory were kept under close observation with a view to discovering some easy means of separating these two species, but all attempts to do so failed. The distribution of the excrement, the orientation of the pupae, and the emergence-holes are exactly the same in both species.

Description of Stages.

Egg (fig. 2, f).—The egg was never found after oviposition. When mature within the ovary it is broadly oval, less elongated than that of *Comperiella*, and is provided with a rigid, hollow vesicle borne on the end of a curved stalk, which is unusually short.

Larva.—The larva, at all ages, is identical with that of *Spaniopterus crucifer* in almost every respect. The mandibles afforded the only certain means of identification. Their shape is similar to that of *S. crucifer*, but their more compact form is a characteristic feature. Some specimens differed slightly from *S. crucifer* in the arrangement of the anterior projecting portions of the fat-body, but since considerable variation occurred these differences cannot be cited as specific characters.

9. *Scymnus severini*, Wsc.

This Coccinellid was found commonly in Java wherever *A. destructor* was abundant. It feeds also upon *C. ficus pallens* but apparently prefers *A. destructor*, presumably because of the softer scale. Scales of all ages and both sexes are attacked, and the

beetle is predacious in both its larval and adult stages. It is a true predator, not merely a scavenger.

Description of Stages.

Egg.—The egg is shaped like a duck's egg, but is rather more elongate, and more pointed at the narrower end. It is bright yellow, translucent, smooth, and shiny. The chorion is perfectly transparent and very delicate, and the shape of the egg therefore varies considerably according to the degree of pressure exerted on it by surrounding objects—usually an *Aspidiotus* covering-scale, since the egg is laid under a scale. The length of the egg is about half the diameter of the scale of a mature female *Aspidiotus*.

Larva.—The 1st instar larva is of a uniform pale green colour and without markings. It bears long setae in the positions described below for the full-grown larva. After the 1st moult the larva acquires an entirely different appearance, which is due to the formation of a number of long white waxy tufts on its back and sides, and these entirely hide the body. They arise from glands on the tubercles which bear the setae, and their number, form, and positions are constant in all instars from the 2nd onwards. In the 1st instar the tufts are represented by a few extremely fine waxy filaments round the tubercles, but these are so minute and flimsy that the larva appears quite naked except under the microscope. Immediately after the 1st moult, however, the filaments are produced in profusion, and those of each tubercle become tangled and matted together as they grow, until they finally form a prominent tuft. The arrangement and size of the tufts are useful specific features for distinguishing this species in the field. The typical Coccinellid form of the full-grown larva is effectively camouflaged by the tufts, but if these are removed—as they easily can be, either by means of a needle or by shaking in water—the larva is seen to be of the normal form, though considerably flattened. The colour of the full-grown larva is normally pale green, like the young, but occasionally it acquires a reddish-brown tinge. There are no markings except for a few dark brown patches on the head. The ocelli are black.

The segments are very distinct and 12 in number. The 1st thoracic segment hides the head and is nearly rectangular in outline. On segments 1–11 inclusive the tubercles form three series on either side of the middle line—dorsal, dorso-lateral, and lateral—each segment bearing one pair of each series. The dorsal series are very near the middle line and are small; the dorso-laterals are rather larger; and the laterals, which are on the extreme edge of the body just above the spiracles, are the largest and very prominent. In addition, each thoracic segment has one extra pair of tubercles situated on the antero-ventral faces of the lateral tubercles and projecting forwards and downwards. The size of these additional pairs decreases from the 1st segment to the 3rd, and that on the 1st is actually larger than the lateral pair and forms a prominent pair of antero-lateral projections in front of the larva. Each of the dorsal and dorso-lateral tubercles bears one straight apical seta and a short, thick, and strongly-curved seta arising on the side of the tubercle near the apical one. The setae on the lateral tubercles are the same, except that there are several of the curved setae instead of only one. All the setae, except those at the apices of the lateral tubercles, terminate in a knob.

The waxy tufts, when examined under the microscope, resemble cotton-wool. The glands from which they arise are apparent as slightly roughened rings round the bases of the tubercles, and consist of a large number of minute pores, each of which produces an extremely fine thread of wax. All the tubercles, except the three additional pairs on the thoracic segments, are surrounded at their bases by these glands and therefore bear tufts.

Since it arises from pores arranged in a ring, each tuft has the form of a hollow cylinder or, in some cases, an elongated cone. The apical seta of the tubercle projects

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up the lumen of the tuft and gives it rigidity, and the subsidiary curved seta is embedded in the substance of the tuft. The curved seta, and the knob on the end of each seta, apparently serve to hold the tuft in place.

The sizes of the various tufts in different individuals are approximately constant. The dorsal series are very short and regular, and the two on each segment almost meet mid-dorsally. The dorso-lateral series are much longer, their length being equal to about half the greatest width of the body, except those on the 11th segment which are much longer. The latter project backwards, like two long tails, and curve towards one another. The dorso-lateral tubercles on the 1st segment are displaced forwards so as to be on the anterior edge of that segment, and therefore the dorso-lateral tufts of that segment project forwards and outwards, overhanging the head. All the other dorso-lateral tufts project laterally, at right-angles to the body.

The action of the glands of the lateral tubercles is curious. All of them are capable of producing waxy threads, yet lateral tufts only develop on the thoracic segments, where they project below and beyond the dorso-lateral tufts. On the abdominal segments the lateral tufts are represented only by a few scarcely visible threads on the surface of the skin.

The tufts hide the larva so completely that it is impossible to tell which is the anterior end until this arrangement is studied. In fact, the two exceptionally long tufts which always develop at the posterior end give the impression that that end is anterior.

Pupa.—The pupa is of the same colour as the larva, that is, either pale green or light reddish brown. The colour does not alter as development proceeds, as the adult does not assume its permanent colouring until after emergence. There is a pair of broad brown bands down the middle of the dorsal surface. On the abdomen the two bands are sharply defined and separated only by a very thin median line, but anteriorly they are much more widely separated and are ill-defined and interrupted intersegmentally. The pupa is hairy all over. The hairs on the lateral, ventral, and anterior surfaces are very small and closely packed, forming a fine pubescence; while those on the back are long, few in number, and arranged in regular rows.

Life-history.

Egg.—The eggs are usually laid inside empty covering-scales of *Aspidiotus* or *Chrysomphalus*, and were never found exposed on the leaves. The duration of the egg stage is 5 days.

Larva.—The young larva breaks the egg-shell at the wider end and immediately crawls out of the scale through the hole by which the egg was inserted. The larva is very active at all ages, and crawls over the leaf at a considerable speed. The sucker-like anal segment is prehensile, and is always used in the same manner as the anal claspers of a lepidopterous larva. The larva begins feeding as soon as it leaves the egg. It prefers young *Aspidiotus*, but in the absence of these it will attack *Aspidiotus* of any stage, including eggs. When about to feed, the larva bites a minute hole in the scale, from which a small drop of the body-fluid issues, and the larva sucks it up and continues sucking until the *Aspidiotus* is empty. The larva never pushes its way under the scale, and when young it never actually eats its victim, its food being obtained by sucking. As soon as it has emptied one individual it moves to another, feeding being almost continuous.

The full-grown larva is very voracious, and was more often found feeding upon the eggs than on any other stage. When it is feeding on eggs its behaviour is necessarily different from that which obtains when it is feeding on scale-insects. In order to get at the eggs it first rips off a part of the scale and then devours the exposed eggs at a great rate, eating the shells as well as the contents.

There are four larval instars, and growth is very rapid, the total duration of the larval stage being only 8 days. At each moult the old skin, together with the waxy tufts, remains attached to the leaf, and new tufts develop within 24 hours. When about to pupate the larva becomes short and plump, and attaches its anal extremity firmly to a silken pad which it spins on the leaf.

Pupa.—The larval skin splits mid-dorsally, and the pupa, by energetic wriggling, pushes it backwards to the end of the abdomen, where it remains. The pupa always bears some of the waxy tufts of the larva, though it does not produce any of its own. Most of them are shed with the skin, but during the act of pupation some of them become impaled on the bristles at the side of the thorax, and these camouflage the pupa effectively. The duration of the pupal stage is $4\frac{1}{2}$ days.

Adult.—The adult is even more voracious than the larva. It feeds largely by biting rather than sucking, and, like the full grown larva, seems to prefer eggs when it can get them. It flies when in search of scale and when disturbed, but having once found a large batch of scale it does not normally leave it. Sometimes it devours *Aspidiotus* individuals which contain internal parasites, and it also destroys the pupae of the external parasite, *Aphelinus Javanophilus*. Since an *Aspidiotus* nearly fills the scale which covers it, and the egg of the beetle is comparable in size to an *Aspidiotus*, it is impossible for the adult beetle to oviposit in a healthy scale without removing the scale-insect. This it does in a very deliberate manner. It first bites a hole in the scale, then grips the edge of the *Aspidiotus* with its mandibles and pulls very gently and steadily by slowly straightening its fore-legs. The hole is very much smaller than the surface of the scale-insect, and the latter therefore crumples up when the beetle pulls it through the hole. A sudden pull would break the *Aspidiotus* in half, but actually the very gentle pulling results in the removal of the insect intact. The beetle then oviposits in the empty scale, and sometimes two eggs are laid in one scale. Female scales are usually selected for oviposition, but not invariably. Frequently the beetle selects old scales from which one of the internal parasites of *Aspidiotus* has emerged, and which are therefore already empty.

Life-cycle.—This was worked out in Java, and proved to be as follows:—Incubation 5 days, 1st instar 1 day, 2nd 2 days, 3rd 2 days, 4th 3 days, pupal period $4\frac{1}{2}$ days; total $17\frac{1}{2}$ days.

10. *Scymnus* sp.

This insect appears to be rather more local in its distribution in Java than *S. severini*, but it is usually very abundant wherever it occurs. Like *S. severini*, it is a true predator. In appearance these two species are very similar in all stages, but the various points of difference enumerated below will serve to distinguish them.

Description of Stages.

Egg.—The egg is pale greenish-yellow and shiny. The surface is minutely reticulated, but the reticulations are only apparent when highly magnified. In shape the egg is similar to that of *S. severini* but less elongate and the narrower end is much less pointed.

Larva.—The 1st instar larva differs from that of *S. severini* in that it develops lateral waxy tufts similar to those of the later instars. The dorsal and dorso-lateral tufts, however, do not develop until the 2nd instar. The 1st instar larva of *S. severini* is entirely devoid of tufts. The most noticeable difference in the full-grown larvae of the two species is that the dorso-lateral and lateral series of waxy tufts are very much longer in the present species. They are also more slender, flimsy, and translucent, and have a bluish tinge. The greater translucency and the tinge are due to the fact that the minute threads of wax of which the tufts are composed are

much less densely packed together. The same three series of tufts—dorsal, dorso-lateral and lateral—are present, but in this species the dorsal tufts are flatter and the dorso-laterals and laterals are much longer. Further, lateral tufts are well developed on all the abdominal segments except the first, and in this respect this species differs from *S. severini*. The dorso-lateral tufts are all very long, and their length increases progressively towards the posterior end, the last pair often being as long as the body. On the thoracic segments the lateral tufts are as long as the dorso-laterals; the abdominal laterals are shorter than the thoracic laterals or are hidden by the dorso-laterals.

Pupa.—The pupa differs from that of *S. severini* in that the dark longitudinal bands are more interrupted, consisting of paired segmental blotches. Moreover, on the prothorax, the metathorax, and the 1st abdominal segment the bands are not represented at all and there are no markings of any kind.

Life-history.

It is unnecessary to detail the habits of this insect, since they are identical, with one exception, with those of *S. severini*. The exception is in the mode of pupation, for whereas the old larval skin of *S. severini* is almost completely shed, being pushed back to the hind end of the pupa, that of the present species is not shed but remains enclosing the pupa except for a mid-dorsal split. The waxy tufts become somewhat tangled in the process of pupation but remain projecting from the old larval skin on each side of the pupa, which therefore acquires a rather unkempt appearance.

The usual situation taken up for pupation is in the groove formed by the midrib of the leaf. Frequently a number of pupae are assembled together in this situation, forming a conspicuous whitish patch on the leaf on account of the waxy tufts.

The adults, on splitting the pupal skin, do not immediately crawl away, but remain enclosed within the skin for a day or so before they move off and begin feeding.

The period that elapses between emergence and mating was found in captivity to vary from 2 to 9 days, and that between emergence and the commencement of oviposition from 6 to 11 days. Subsequently a few eggs were laid nearly every day, the average daily number being about 3, and the maximum 7. The egg capacity appears to be at least 100.

The adults flourish in glass tubes when fed only with *Aspidiotus* and live for at least a month in these conditions. One female lived for 3 months.

Life-cycle.—This was found in Fiji to be as follows:—Incubation $5\frac{1}{2}$ days, 1st instar $3\frac{1}{2}$ days, 2nd 3 days, 3rd 3 days, 4th 5 days, pupal period 5 days; total 25 days. These figures were obtained in the cooler months in Fiji. In the hotter climate of Java the total period did not exceed 3 weeks, but no figures for the separate stages were obtained.

11. *Scymnus apiciflavus*, Mots.

This species was occasionally found associated with *Aspidiotus* and *Chrysomphalus* on coconuts in Java. It was never abundant on coconuts, however, and was not studied in detail.

12. *Pharellus minutissimus*, Sic.

This small Coccinellid is commonly associated with *Aspidiotus palmae* on coconuts in Java, but rarely with *A. destructor*. It is more a scavenger than a predator, though it frequently does attack healthy scales. The larvae bear prominent tubercles and are hairy, but have no waxy appendages. They cover the patch of scales amongst

which they find themselves on emerging from the eggs with a fine web, and live and pupate beneath it.

13. *Aleurodothrips fasciapennis*, Frankl.

In Ceylon this thrips has been reported as attacking *Aspidiotus* sp. and in Florida it is an enemy of *Aleurodes citri*. In Java it was found commonly feeding upon *Chrysomphalus ficus pallens* and *A. destructor*. It is a true predator, obtaining its food by sucking scale-insects, just as other species of thrips suck plant tissues. It is interesting to note that, according to Morrill & Back,¹⁴ this insect "proved more effective than any other of the native insect enemies of the citrus whitefly," in Florida.

The egg is laid under empty covering scales of *Aspidiotus* and *Chrysomphalus*, and also inside the dried cuticles of those scale-insects from which internal parasites have emerged, the thrips gaining access to the interior through the exit-holes. The egg is rounded at one end and tapers to a point at the other, which bears a minute appendage or stalk.

The nymphs, like the adults, feed on scale-insects. The adult feeds voraciously, rushing rapidly from scale to scale and feeding almost constantly for long periods. It stops at each scale for about half a minute as a rule, and in such cases the scale is by no means emptied, but occasionally it sucks one scale for several minutes and almost completely empties it. Sometimes it seizes an individual of *A. destructor* with its forelegs, pulls it out of the covering scale and holds it up while feeding on it, as a mantis holds a moth.

14. Other Predators.

Other predators found in association with *Aspidiotus* and *Chrysomphalus* included a Chrysopid, a Cecidomyiid, and several species of ants and mites. Larvae of the two first-named insects were occasionally seen devouring healthy Coccids, and the Cecidomyiid appeared to confine itself to Coccids, but the Chrysopid is certainly a general feeder. Neither is sufficiently plentiful as an enemy of Coccids to be of economic importance.

Very little is known of the part played by ants and mites as natural enemies of *Aspidiotus*. Ants do not appear to be of major importance in this respect, though they are frequently seen carrying off healthy individuals of *A. destructor*. Mites, on the other hand, probably play a larger part in the control of Coccids in Java than is generally believed, and there is great need for a thorough investigation of the matter. Many different species of mites are almost invariably present in large batches of *A. destructor*, and though most species are undoubtedly merely scavengers, there are some which have been observed to attack healthy scales. In Java, mites were often observed feeding on healthy eggs of *A. destructor* and very frequently batches of scales die off suddenly, especially when small, although there is no indication of their having been attacked by insect parasites or predators, or by fungi.

VI. SOME NATURAL ENEMIES IN TRINIDAD.

In the investigations conducted in Trinidad, attention was paid only to the predators. Parasites were comparatively scarce and certainly play no great part in the control of *Aspidiotus destructor* there.

Coccinellid beetles are by far the most plentiful of the predators. Five species were found commonly in nearly all localities where the scale itself was common. These were:—*Cryptognatha nodiceps*, Mshl., *C. similima*, Sic., *Azya trinitatis*, Mshl., *Pentilia insidiosa*, Muls., and *Scymnus aeneipennis*, Sic.

Methods of breeding and shipping these five Coccinellids, all of which were eventually imported into Fiji, were devised in Trinidad and their life-cycles and habits were studied in more detail later in Fiji.

Most of the material was collected at Cedros, on the south coast of Trinidad, and at Manzanilla, on the east coast. It was then taken by car to the Imperial College of Tropical Agriculture at St. Augustine, where the bulk breeding was done.

The habits and structure of these five species are similar in all stages, but the differences are sufficiently great to render identification in the field a comparatively easy matter. It may be worth while to outline those points of difference which were found most useful in the field for identifying the species in their early stages, particularly when several species occurred together in large numbers on the same trees.

The eggs differ slightly in shape, size, colour, and surface reticulations. There are also differences in the positions in which they are laid, for whereas four of the five species always lay their eggs inside the scales, the other species always lays them on the leaf without any definite covering.

The larvae begin feeding soon after they emerge from the eggs and are very active and voracious. The larval habits are the same in all species, except as regards the degree of voracity. In four of the five species the larva bears long white waxy tufts which hide the body. The arrangement of the tufts is constant for each species and is a most valuable means of identification; in two species however, the tufts are exactly the same, but the body-colour is quite different and shows through the tufts sufficiently for the recognition of the species. The fifth species has no tufts.

The pupae are more easily distinguished than the eggs or the larvae, the chief points of difference being colour, markings, presence or absence of prominent setae, and the disposition of the waxy tufts of the larva, which remain attached to the pupa. Also, one species differs from all the others in the site chosen for pupation.

1. *Cryptognatha nodiceps*, Mshl.

This species was found in extraordinary abundance in Trinidad wherever *Aspidiotus destructor* occurred in outbreak form, and was present in small numbers even in those localities where the scale was rare. It appears to confine itself largely to *A. destructor*, and is always closely associated with it. It will not eat hard scales. In Fiji it feeds on *Diospis pentagona* as well as on *Aspidiotus destructor*, and probably resorts to any soft scale when it cannot get *A. destructor*. It is a true predator, and never a scavenger.

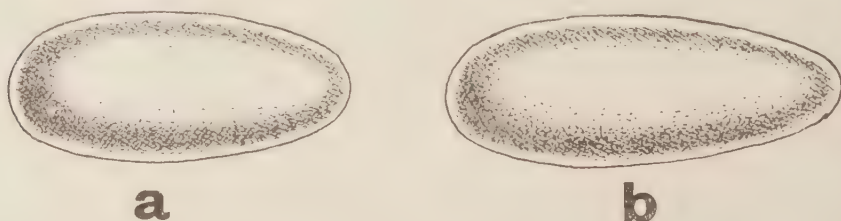


Fig. 14. Eggs of *Cryptognatha*: a, *C. nodiceps*; b, *C. simillima* (both $\times 110$).

Description of Stages.

Egg (fig. 14, a).—The egg is of the usual Coccinellid form, and 0.42 mm. in length. Both ends are rounded but one is much broader than the other. The broader end is anterior and micropylar. The shape varies considerably according to the degree and direction of the pressure exerted by surrounding bodies, notably the covering scale of *Aspidiotus*, and often it is greatly flattened between the latter

and the leaf. The colour is pale translucent green throughout. It often appears yellow when surrounded by the yellow eggs of *Aspidiotus*, but this colour is transmitted from its surroundings. The surface is very shiny, and the chorion is very thin, delicate, and pliable.

The chorion of a typical egg is minutely reticulated, but the reticulations are only apparent under the microscope. Most of the meshes comprising the reticulations are either pentagonal or hexagonal. The various lines or thickenings of the chorion, which make up the network and which appear to be continuous, actually consist of a double row of minute dots, or swellings like tiny lenses, in the chorion. The arrange-

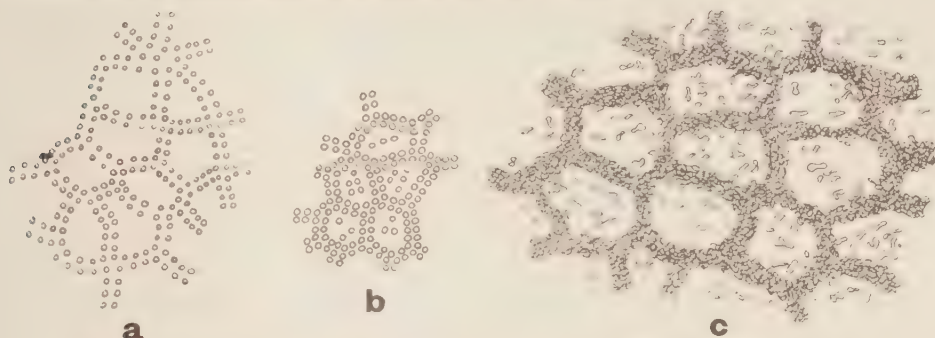


Fig. 15. Reticulations on chorion of egg of: **a**, *Cryptognatha nodiceps*; **b**, *Cryptognatha similima*; **c**, *Azya trinitalis*.

ment of these dots is an important specific feature (fig. 15, **a**). The reticulations, however, are often absent altogether, or present only in places. Their absence is due to the fact that the egg comes into contact with the leaf and the scale immediately it leaves the ovipositor and before its surface is dry, so that the reticulations become obliterated.

First instar larva (fig. 16).—When newly-hatched it averages 0.61 mm. in length, and is of a light, translucent, yellow-green colour (occasionally blue-green). As soon as it begins feeding it turns more yellow and becomes more opaque. The head is slightly darker than the body. The segmentation is clearly marked, there being 13 body-segments, of which only 12 are visible from above since the 13th is small, prehensile and button-like, and hidden by the 12th. The thoracic segments are much longer than the abdominal, the latter being short and all of equal length except the 12th, which is about twice as long as the others.

The head bears many setae (fig. 16, **a**), some very long, and two pairs of minute sensory pits. The larger setae only are knobbed at their extremities. The ocelli are prominent. The dorsal region of the body bears four double rows of minute setae (two rows on either side of the middle line). Every seta is mounted separately on a minute tubercle. The dorsal row is represented on the 1st segment by two pairs of setae, one behind the other, on segments 2-11 inclusive by a single pair, and on segment 12 by a single seta. On the first two segments the outer tubercle and seta of the dorsal row are larger than the inner; on the other segments the inner are the larger. The dorso-lateral row is represented on the 1st segment by four minute setae arranged as in the figure, on the 2nd segment by two setae a short distance apart, on segments 3-11 by two setae side by side, and on the 12th by a single seta. The size of the dorso-lateral tubercles and setae is the same as that of the smaller ones in the dorsal series. The lateral series of setae include a single row of long setae, there being one at the extreme lateral point of every segment, projecting outwards. The 12th segment bears in addition two other prominent setae on each side. The relative lengths of the prominent lateral setae are constant

and are accurately shown in the figure, and there is a row of minute setae, similar to those of the dorso-lateral series, just above them. This row is represented on segments 1 and 2 by a group of three, on segment 3 by two (occasionally three), and on the abdominal segments by one. All the dorsal and lateral setae are knobbed. The ventral surface of the body bears a few very minute setae, which can only be detected with a high-power microscope. Their arrangement and relative sizes are constant and are shown in fig. 16, *b*. In addition to the setae the body is uniformly covered all over with innumerable, excessively minute microtrichia.

The appearance of the 1st instar larva in life is very different from that in fig. 16 on account of the white wisps and tufts of wax which camouflage the outline and colour of the body, and entirely hide the setae. The wax is produced from glands in the tubercles, which give rise to a thin and flocculent covering of wax all over

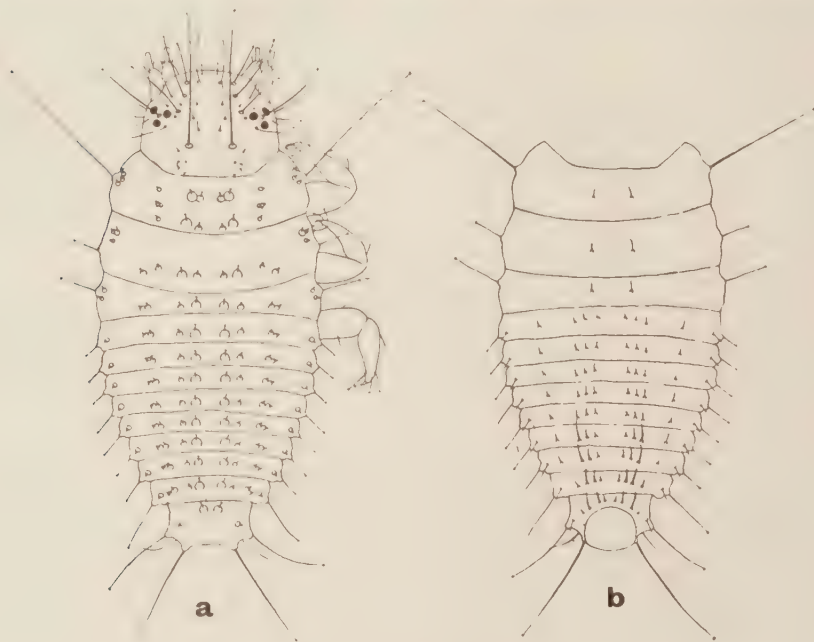


Fig. 16. *Cryptognatha nodiceps*, 1st instar larva ($\times 105$), *a*, dorsal view; *b*, ventral view (head and legs omitted).

the dorsal surface. In addition, the lateral prominences give rise to white tufts of wax, one on each side of each segment, and these project laterally as a fringe. There is also a long, thick tuft projecting backwards, like a tail, from segment 12. There is great variation in the size of the tufts in the 1st instar, but they are always much shorter, relative to the dimensions of the body, and less definite than in subsequent instars. Otherwise they correspond with those shown in fig. 19.

Full-grown larva (figs. 17, 18).—The length of the full-grown larva varies greatly, according to the food-supply and to the degree of extension, but is approximately 3.0 to 4.0 mm. (*i.e.*, without the waxy tufts). Its colour normally appears to be whitish, but this is due to the waxy covering. The actual colouring of the body and head is bright yellow, as a rule, but varies from greenish yellow to orange, according to the colour of the scales which constitute the food. The head and the thoracic segments are darker and browner than the abdominal ones. The head is almost completely hidden by the first segment, into which it can be partly retracted.

The first segment differs in shape and chaetotaxy from all the others: it also differs in that it possesses, on its dorsal surface, a pair of large brown spots, rather vague in outline, which are due to chitination of the cuticle; otherwise the body is entirely without markings. There are 9 pairs of spiracles, and 8 pairs of inter-segmental pores, situated as shown in fig. 17, **a**.

The chaetotaxy is accurately shown in the figure. It exhibits a marked uniformity on all segments except the 1st, 12th and 13th. The 1st is covered anteriorly and laterally with small setae, and on its anterior margin bears a pair of long setae, which probably represent the anterior dorsal setae of the 1st instar. The conspicuous prominences at the antero-lateral corners bear two long setae, one terminal and one subterminal. There are no dorso-lateral tubercles or setae, these probably having fused with the laterals. Each of the remaining segments from 2 to 11, inclusive, bears, on either side of the middle line, a dorsal, a dorso-lateral, and a lateral tubercle, the latter being very prominent. There are no pairs of tubercles as in the 1st instar.

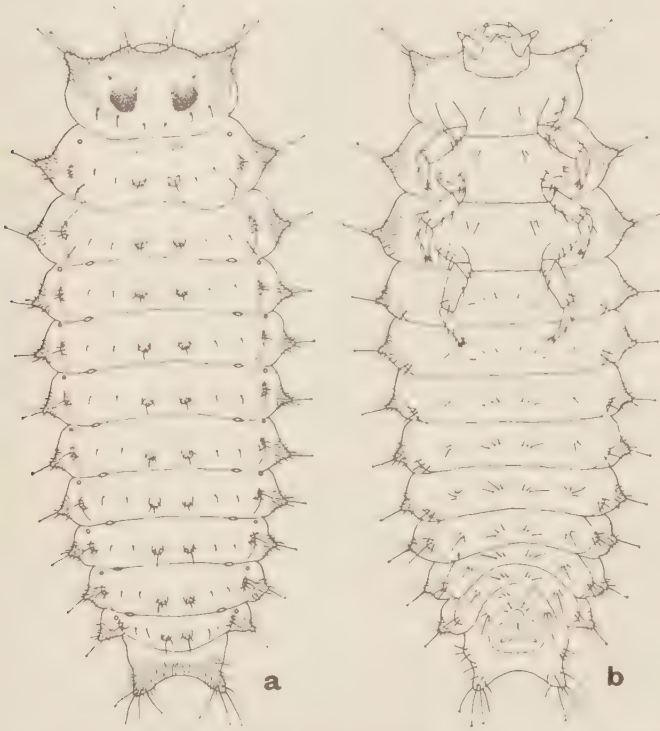


Fig. 17. *Cryptognatha nodiceps*, full-grown larva, after removal of waxy tufts ($\times 22.5$): **a**, dorsal view; **b**, ventral view.

The dorsal and dorso-lateral tubercles bear a few (3-6) short setae and one more prominent apical seta. Between the dorsal and dorso-lateral tubercles there are, on each segment, two separate setae not mounted on definite tubercles. The lateral prominences are covered with many small setae and terminate in one much longer and stouter seta. The 12th segment projects at its postero-lateral corners to form very prominent tubercles, one on either side, each of which bears four stout setae. The whole of the posterior half of the segment, including the tubercles, is covered with short setae like those on the 1st segment. All the larger setae on the dorsal and lateral surfaces are knobbed. The ventral surface bears a few setae, arranged

as in fig. 17, **b**; none of these is knobbed. The whole surface of the body is densely and uniformly covered with very minute microtrichia (not shown in figures).

The legs are relatively small when the larva is full-grown and are only visible ventrally. The setae are the same on all the legs. The distal segment carries at its extremity a single large claw and about 6 stout setae, each of which is knobbed. None of the other setae is knobbed.

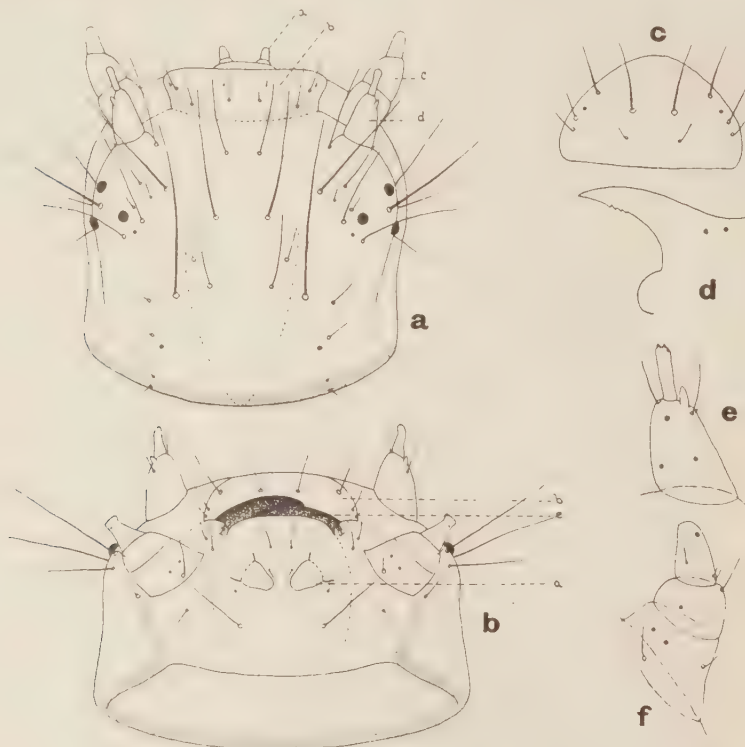


Fig. 18. *Cryptognatha nodiceps*, head-capsule of full-grown larva: **a**, antero-dorsal view ($\times 100$); **b**, ventral view ($\times 100$); **c**, labrum ($\times 150$); **d**, mandible ($\times 175$); **e**, antenna ($\times 175$); **f**, maxillary palp ($\times 175$). *a*, labial palp; *b*, labrum; *c*, maxillary palp; *d*, antenna; *e*, mandible.

The head-capsule (fig. 18) bears no markings, and the only sutures visible dorsally are those which separate the central epicranial sclerite from the side-walls or genae, and at the middle point of the posterior edge of the head they meet so as to form a V-shaped mark, the two arms of which are curved and paler and more transparent than the dorsal surface in general. When the head is viewed antero-ventrally the labial, gular, and maxillary sutures are apparent as dark, strongly-chitinised, thick lines. The chaetotaxy of the head is identical with that of the 1st instar larva except that certain of the setae which are relatively small in the 1st instar are large and prominent in the 4th instar.

All the features hitherto described are ordinarily obscured by the waxy deposit, which almost entirely covers the larva, except ventrally, and makes it look white (fig. 19). The back is covered with powdery wax, except for a pair of small areas on the 1st segment, which are actually the dark chitinised spots already mentioned, and similar areas situated subdorsally between the 1st and 2nd segments and the 2nd and 3rd. These small areas devoid of wax make the thorax look as if it bears

three pairs of pigmented spots, but actually there are no definite spots. Laterally the deposit of wax on the back does not extend quite as far as the lateral prominences, so that there is a narrow band devoid of wax along each side, between the dorso-lateral and lateral tubercles. There is no wax on the 13th. In addition to the general covering of wax there are three series of waxy tufts on either side of the middle line corresponding to, and formed by, the dorsal, dorso-lateral, and lateral tubercles. The dominant seta of each tubercle serves to anchor and support its tuft in the manner described for *Scymnus severini*. The dorsal and dorso-lateral tufts are very small, short, irregular, and flimsy. They are so fragile that they often become displaced, or merged with the general dusting of wax. The lateral tufts are extremely long and the waxy threads of which they are composed are so tightly

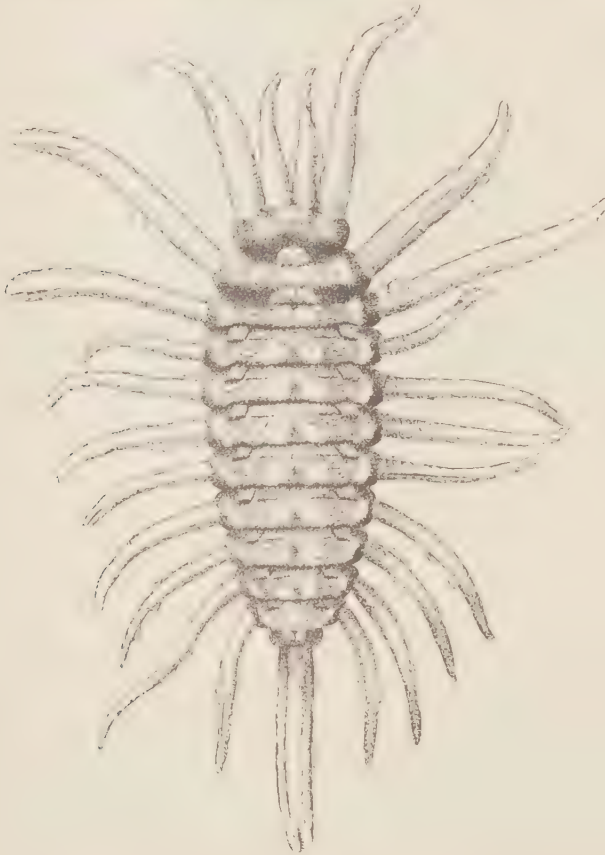


Fig. 19. *Cryptognatha nodiceps*, full-grown larva, normal appearance with waxy tufts (\times about 17).

packed together as to give them a fairly solid appearance and render them perfectly white and opaque. The relative lengths, thickness, and direction of the various tufts, are constant within small limits for all individuals; but the tufts are liable to become displaced and broken by contact with foreign bodies when the larva crawls about. Each tuft, except the most posterior, is almost circular in cross-section. The thick posterior tuft, which arises from the two tubercles of the 12th segment, is somewhat square in cross-section and grooved longitudinally on either

side. The only tubercles, other than the lateral series, which form long tufts are the pair on the anterior edge of the 1st segment. These appear to represent the dorso-lateral series on that segment, and their tufts are long and project forwards, overhanging the head.

Pupa (figs. 20, 21).—The size and proportions of the pupa are fairly constant, provided that the food supply has been abundant. The average length of the pupa (after removal of the old larval skin which remains attached to it) is 2.51 mm., and the ratio of length to breadth is 7 : 5. The greatest width is across the elytra in the region of the 1st abdominal segment.



Fig. 20. *Cryptognatha nodiceps*, pupa, with larval skin and waxy tufts *in situ* (\times about 27).

The pupa is incapable of producing wax, but bears the long waxy tufts of the larva, attached to the old larval skin, at its hind end (fig. 20). These tufts are more or less matted together and project laterally, while the posterior tuft of the larva is directed backwards, looking like a stalk for the pupa. The old larval skin and the wax completely cover all the segments behind (but not including) the 4th abdominal, and fit so closely round them that it is difficult to extract the pupa without damaging it. The position of the larval skin, relative to the abdominal segments, is absolutely constant.

The pupa, unlike the larva, is conspicuously marked, and there is considerable variation in the markings. The ground-colour is light brownish-yellow. In the typical pupa, there are prominent dark brown markings on the thorax and abdomen, arranged and shaped as in fig. 20. The prothorax and elytra are devoid of markings except for the small spots shown, and even these are occasionally absent altogether. There is great variation in the extent and intensity of the dark brown blotches on the meso- and metathorax and the abdomen. The skin is somewhat shiny. The dorsal surface is strongly chitinated, particularly on the first four abdominal segments.

There are eight abdominal segments altogether, and the last of them bears a pair of strong incurved processes with slightly swollen extremities which are normally embedded in the old larval skin and serve to attach the pupa to it. There are six pairs of spiracles. The first pair is situated at the sides of, and near, the anterior edge of the mesothoracic segment, and cannot be seen dorsally. The second is at the anterior edge of the 1st abdominal segment just in front of, and below, the prominent lateral tubercles, being overhung and protected by a small chitinous lobe which projects from the tergite of this segment. The other four pairs are similarly situated on the next four segments, each being hidden in the niche between the lateral tubercles of its own segment and that of the segment in front. There are also four pairs of intersegmental pores in the positions shown in fig. 21. These yield a repellent fluid.



Fig. 21. *Cryptognatha nodiceps*, pupa, dorsal view, to show chaetotaxy and repugnatorial pores ($\times 30$).

The pupa is covered, though not uniformly, with small setae which give it a pubescent appearance. There are also many dominant setae which make the pupa look shiny. These are always arranged, except for slight changes in position, as in fig. 21. The abdominal segments, like those of the larva, have three series of setae. All the dominant setae are mounted on dark brown tubercles, but the tubercles of the lateral abdominal series are by far the most prominent. The lateral series is represented on each of the first four abdominal segments by two setae. The last three segments differ from the others in that the dorsal and dorso-lateral setae are much smaller, there being no lateral setae at all, and the tergites are less strongly chitinised. These differences are associated with the fact that the old larval skin completely covers these segments. None of the setae is knobbed, but all of them are glandular and produce at their extremities minute drops of colourless fluid which remain attached to them continuously, or are replaced if removed.

Adult Variation.—The dark markings of the adults are subject to great variation, and there is not the slightest resemblance between extreme forms. One of the most

common forms is that in fig. 22. Another and equally common form is figured in the original description of the species (*Ann. Mag. Nat. Hist.* (8) **10**, p. 322) and less common variations are shown in fig. 23. Specimens which are almost entirely black

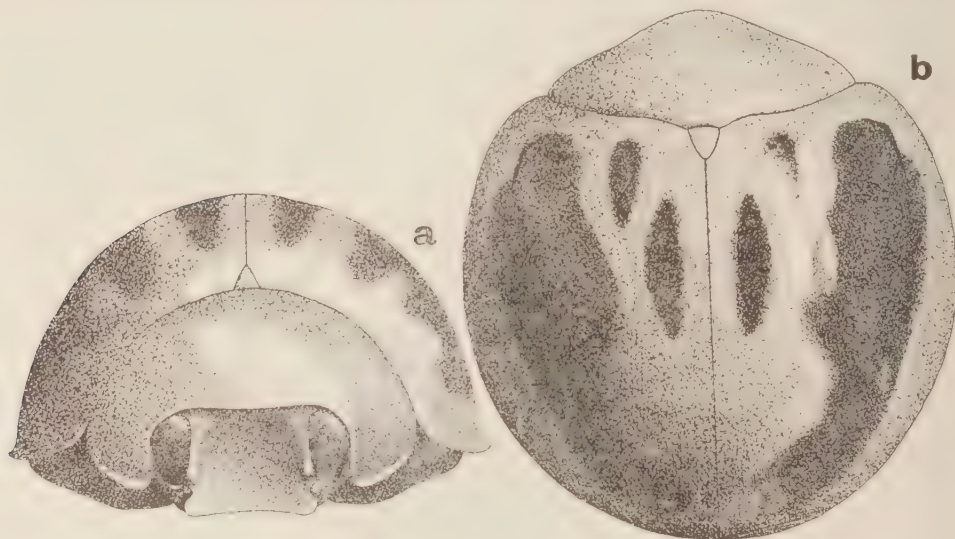


Fig. 22. *Cryptognatha nodiceps*, adult, **a**, anterior view; **b**, dorsal view

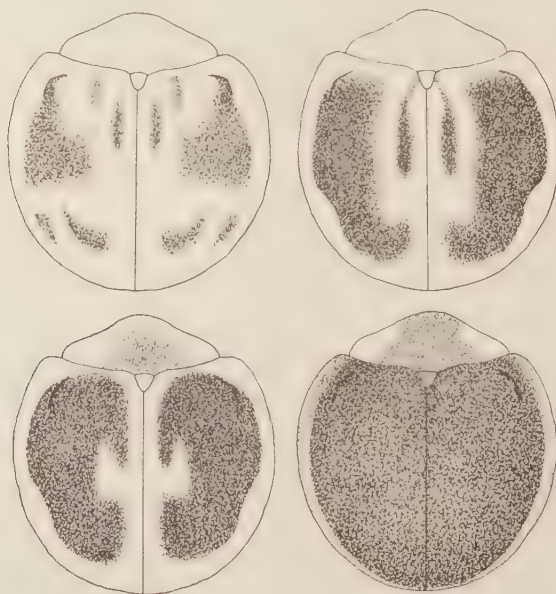


Fig. 23. *Cryptognatha nodiceps*, variation in markings

are not uncommon. It is interesting to note that when the species became established in Fiji it became on the whole much darker than in Trinidad. There was a tendency for the black markings in the average specimen to cover a much larger area than in Trinidad, and the light varieties are much rarer in Fiji.

Structural details of the head and mouth-parts are shown in figs. 24 and 25. There are no sexual differences in colouring or markings. The head, however, affords



Fig. 24. *Cryptognatha nodiceps*, mouth-parts and antenna of adult: **a**, labrum ($\times 100$); **b**, mandible (right, $\times 100$); **c**, maxilla (right, $\times 112.5$); **d**, antenna (right $\times 175$); **e**, labium, mentum and submentum ($\times 112.5$).

ready means of distinguishing the sexes (figs. 22 **a**, 25). The semi-circular depression in the front of the head is much deeper and more noticeable in the male, and the tubercle on either side, near the eye, is much more prominent in the male.

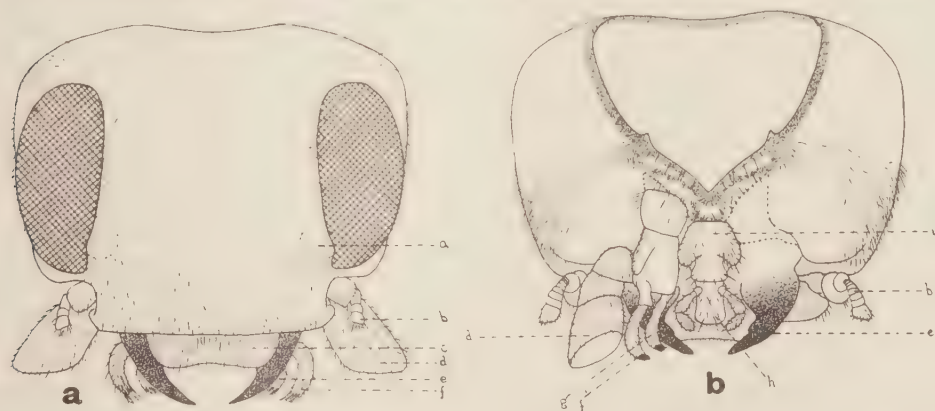


Fig. 25. *Cryptognatha nodiceps*, head of adult, **a**, anterior, **b**, posterior view (right maxilla omitted): **a**, papilla; **b**, antenna; **c**, labrum; **d**, maxillary palp; **e**, mandible; **f**, galea; **g**, lacinia; **h**, labium; **i**, submentum.

Life-history.

Egg.—The eggs are laid singly underneath the covering scales of *Aspidiotus destructor*. Occasionally two are laid, side by side, under the same scale. Very rarely the egg is deposited directly on the leaf without anything covering it, but this is quite abnormal. The scales selected by the beetle for oviposition are usually those from which it, or another beetle, has already removed the scale-insect, partly

or completely, by devouring it. The largest scales (*i.e.*, mature females) are preferred. The length of the egg is comparable to the diameter of a mature female *Aspidiotus*, and the egg is therefore readily seen through the transparent covering scale as a yellow oval mass in the position normally occupied by an *Aspidiotus*. Often it is surrounded by the tiny, similarly shaped eggs of *Aspidiotus*, these having been left by the beetle when it devoured the parent scale-insect. When first laid, the egg is sticky and therefore adheres strongly to the leaf and usually to the covering scale also. It dries very rigidly, and when permanently stuck to the covering scale is more clearly seen than an *Aspidiotus* in the same position. This fact greatly facilitates the discovery of eggs of the beetle in a large batch of scales, with the aid of a hand-lens only.

Larva.—The young larva ruptures the end of the egg when fully developed, and crawls out, leaving the transparent, flimsy egg-shell, which is now difficult to detect, still inside the scale. The larva rests for about an hour after leaving the egg and then becomes very active and begins feeding voraciously. Its pale green colour changes to greenish yellow when it starts feeding, on account of the colour of the food.

Since there are often a number of *Aspidiotus* eggs in a scale in which *C. nodiceps* oviposits, the newly-hatched larvae of the latter find themselves surrounded in such cases by eggs and newly-hatched larvae of *Aspidiotus*. They avail themselves of this ready supply of food at once, and may remain feeding inside the scales in which they have emerged from their eggs for a day or more. When no food is available in the scales in which the eggs hatch, the young larvae crawl out and wander in a rapid and determined manner over the leaf until they find some living *Aspidiotus*. They seem to prefer small, 2nd stage scales at this time. They grow rapidly, and after the first moult (*i.e.*, after a couple of days) attack scales of any age and either sex. They are extremely voracious, and feed almost continuously. The total number of full-grown scales destroyed by one larva in the course of its life was not estimated accurately, but is probably more than 200. The larva moults three times in the course of its growth, there being four larval instars altogether. The cast skins, with their waxy tufts, remain attached to the leaf. The resting period prior to each moult is very short, often being only 6 hours, and always less than 12 hours. Feeding recommences about an hour after each moult.

The waxy tufts are necessarily shed with each skin, and new ones develop after each moult. The young larva begins to secrete the wax as soon as it emerges from the egg, but the amount of wax produced in the 1st instar is very variable, some larvae having definite lateral tufts and others being almost entirely devoid of wax. In each of the other instars the dimensions of the tufts are constant, within narrow limits. The tufts continue growing for about 24 hours after each moult, but they have then reached their maximum size for that instar and no more wax is produced. When tufts are removed, no others grow to replace them. It is surprising to notice that at the last (3rd) moult the larva very often possesses short, regular, stumpy tufts when it actually crawls out of the old skin. Since it crawls out rapidly, the tufts must have been developed in the old skin before dehiscence occurred. At the earlier moults, all those individuals observed were devoid of wax when they emerged from the old skins. The white waxy tufts make the larger larvae very conspicuous on the leaves as white spots. When the larvae are very numerous they can be seen from the ground on coconut palms 30 ft. high, with the naked eye.

Although, when scale is abundant, the larvae eat nothing else, they become highly cannibalistic when they have eaten all the scale they can find, the large larvae devouring all the small ones and all the prepupae and pupae.

When the larva is touched it emits from each of the intersegmental pores nearest to that part of its body where the touch occurs a large drop of yellow fluid. The

fluid is expelled with great rapidity, and then, if the disturbance ceases, it is sucked back slowly into the body, so that the drops look like bubbles being deflated. If a drop from any one pore is removed as soon as it appears, and the larva is again stimulated in the same place, another drop of equal size is produced. The larva is capable of producing about 3 drops in quick succession from any one pore, but the supply of fluid is then apparently exhausted for the time being. When touched in many places at the same time the larva emits a drop from all the pores at once. The fluid presumably serves as a repellent.

The larvae become gregarious when ready to pupate. They collect together in various situations—at the bases of the leaf-stems, on the leaves, on the fibre at the bases of the leaves, at the top of the trunk, and sometimes even on the coconuts. They show some tendency at this time towards concealment, often collecting at the points where the coconut leaflets join the main stem of the leaf, or in folds of the fibre, but this tendency is not strong enough to explain their gregarious habit, as they also take up exposed positions on the undersides of the leaves where they have been feeding. When massed together the larvae, and subsequently the pupae, form very conspicuous white patches, which, when exposed, can be seen from a long distance. Having selected a site for pupation the larva makes a little waxy and silken film on the surface selected and attaches itself at its hind end only to the film with an adhesive secretion. It then remains stationary and gradually hunches up its back and contracts so as to become short, stout, and rounded. In this process the waxy tufts are brought into contact with one another and become tangled together in untidy masses. This prepupal period, from the cessation of feeding to the act of pupation, covers 2 days.

Pupa.—Pupation is effected by working the larval skin, which splits anteriorly only, back to the hind end, thus exposing the pupa. The tufts are carried back with the skin, being attached to it by the long knobbed setae, and remain accumulated at the hind end of the pupa, from which they radiate. They are very conspicuous on account of their whiteness. The last four segments of the pupa always remain embedded in the larval skin and the wax, but the rest of the pupa is entirely exposed and free from wax. When touched, the pupa, like the larva, exudes the same yellow fluid in round drops from the abdominal pores, and is capable of sucking them back into the body when the disturbance ceases. Persistent irritation causes the pupa to jerk its body up and down rapidly and regularly, at right angles to the surface of attachment, sometimes for half a minute or more. The anterior end is jerked up away from the surface of the attachment and is then brought down sharply, and when a number of pupae are behaving in this way in a confined space a rapid tapping noise results. Except on these occasions, the pupa remains with its ventral surface in contact with the leaf or other surface, and although it is attached at the hind end only it is quite rigid. The pupa remains the same colour throughout its period except for the eyes, which become blackish after two days, and the mandibles, legs, and tips of the wing-cases, which become blackish after 3 days.

Adult.—When ready to emerge, the adult splits the pupal skin anteriorly and mid-dorsally. It crawls partly out of the skin and then levers itself up on its head, with its hind end touching the anterior end of the empty skin. In this position it appears to be standing on its head. Clinging to the anterior end of the skin with its hind legs, it brings its head towards the hind end of the skin, until finally it has turned right over on to its back between the old skin and the leaf or stem of attachment, the head being thrust under the posterior end of the skin. A few hours later, it turns over into a normal position, but is still partly covered by the empty skin. It remains under the skin for about 24 hours, during which time the cuticle hardens and the markings, which are scarcely apparent when it first emerges, develop.

The adult feeds as voraciously as the larva; it devours scale of all ages and both sexes at random, the total number of scale-insects destroyed in its long life amounting

to many hundreds. It does not, as a rule, remove the covering scale completely to get at the *Aspidiotus* underneath, but merely ruptures it near the centre and feeds through the hole. It pulls the *Aspidiotus* towards the hole from time to time, after eating that part of it within reach. It devours eggs extraordinarily rapidly.

The beetles are entirely diurnal in their habits. They fly rapidly from leaf to leaf and tree to tree, but rarely remain on the wing long. Although *Aspidiotus destructor* is usually more plentiful on coconuts than on other trees or plants, the beetles do not appear to be specially attracted to coconuts in their search for food. They detect the presence of scale on bananas, mangos, and other trees as readily as on coconuts. Their ability to detect small batches of scale, even in densely wooded country at times when the scale is very scarce, is most remarkable. In fact, wherever a few scales occur, the beetles are almost invariably present also, even though no appreciable quantity of scale can be found for a mile in any direction. No experiments have been conducted to ascertain what other species of COCCIDAE are attacked, but it appears that their food consists mainly, and probably entirely, of the few Diaspine Coccids which have very soft covering scales. They have never been found to attack LECANIINAE, although several species of scales of this subfamily are present in localities in which the beetles occur, and they do not attack mealybugs. The only scale, other than *Aspidiotus destructor*, on which they have been found feeding and breeding in the field is *Diaspis pentagona*. There is much evidence to indicate that they have a definite preference for *A. destructor*. They are always rare when *A. destructor* is rare, despite the presence of many other species of scales.

The adults feign death when touched, and immediately drop from the leaves, but usually take wing before reaching the ground. Each female pairs more than once in the course of its life. Copulation normally occurs for the first time about four days after the emergence from the pupa, and oviposition commences about a week after emergence. When about to pair the males chase the females, following closely behind them, at great speed over the leaves. When ovipositing the female rests on the scale and thrusts its ovipositor forwards through the hole in the covering scale which it made to devour the scale-insect. Oviposition continues slowly for many weeks. Eggs are laid nearly every day, the maximum recorded in one day being 12 and the average for a fortnight after the commencement of oviposition about four a day. The egg capacity apparently lies between 50 and 120, but varies very greatly according to the food supply and the size of the beetle. It was found in the course of bulk-breeding that the average egg-capacity worked out at approximately 100.

The adult life is very long, lasting several months. The beetles can easily be kept alive in glass tubes for two months when provided with a sufficient supply of fresh *Aspidiotus* every day. A more accurate idea of the duration of the adult life was obtained by enclosing 18 males and 18 females (all one week old) in a white cloth bag on a scale-infested banana leaf in the field, and removing them to a new leaf every other week. Great care was taken to make sure that no larvae or pupae were already on the leaves employed and that none could enter the bags. The beetles fed, paired, oviposited and even flew inside the bag, and their behaviour was apparently quite normal in every way. The following observations were made :—

12th July.	36	adults put in bag.	
27th „	35	moved to new leaf.	1 dead.
4th Aug.	35	„ „	0 „
12th „	32	„ „	3 more dead.
22nd „	29	„ „	3 „
3rd Sept.	23	„ „	6 „
15th „	18	„ „	5 „
2nd Oct.	14	„ „	4 „
25th „	9	„ „	5 „

It was not possible to continue the experiment after 25th Oct., but these figures suffice to show that 25 per cent. of the beetles lived for 18 weeks. The 9 which remained were all females, and all were very active.

On two occasions this species was observed in captivity cross-pairing with *C. simillima*, the male in both instances being *C. nodiceps*. There is, moreover, some evidence to show that the eggs resulting from such a pairing are fertile, for the two adults shown in fig. 26 were subsequently found in the same cage. It will be seen that the markings on the pronotum are those of *C. simillima* (fig. 27) and the markings on the elytra are those of *C. nodiceps*. No examples of true *C. nodiceps* with these markings on the pronotum were ever observed, and there is therefore little doubt that the two specimens figured were hybrids. Unfortunately, no opportunity of investigating this interesting matter further occurred.

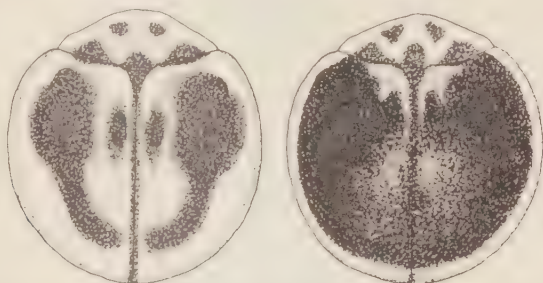


Fig. 26. Two specimens believed to be hybrids between *C. nodiceps* and *C. simillima*.

Life-cycle.—This was worked out in May and June, 1928. The following data were obtained:—Incubation 5–6 days, 1st instar 2–3 days, 2nd 2–3 days, 3rd 2–3 days, 4th 4–6 days, pupa 4 days; total 19–25 days. These figures apply only to individuals whose food supply was ample. When scale is scarce the larvae grow very slowly, and the length of the larval stage may be nearly doubled. The variation shown above in the duration of the various stages is that which occurs normally in any brood. There is always considerable variation in the larval instars, even amongst larvae all of which are reared in apparently identical conditions. For the majority of individuals, however, the total period from oviposition to emergence was found to be nearly constant, averaging 20 days and only varying from 19 to 21 days. It should be noted that when the larvae are crowded together, as they often are when reared in large numbers for distribution, the total duration of the life-cycle is never less than 21 days and is usually about 28 days. This lengthening is due to the limitations of the food supply and to the fact that those individuals which are the first to prepare to pupate are almost always eaten by the others, from which they cannot hide themselves. In the field, when scale is plentiful, there is no such lengthening, although the larvae are often present on the leaves in enormous numbers, the difference lying in the fact that they can spread indefinitely over the leaves during the feeding period and can withdraw, when ready to pupate, to those parts of the trees which are not frequented by feeding larvae. In the hotter months (October to March in Fiji) the rate of development is appreciably greater. For individuals reared separately in ideal conditions, the average duration of the total life-cycle in January 1929 was approximately 18 days, instead of 20 days as in the preceding June.

2. *Cryptognatha simillima*, Sic.

C. simillima (fig. 27) is much less abundant in Trinidad than *C. nodiceps* and much less generally distributed. It was only found in those localities where serious outbreaks of scale occurred, but was plentiful within the outbreak areas. Its food

appears to be restricted, like that of *C. nodiceps*, to *Aspidiotus destructor* whenever that scale is abundant. It is extremely closely allied to *C. nodiceps*. Cross-pairing between the two species apparently occurs in captivity. Their habits are identical in every particular. Except for certain minute details in chaetotaxy there are no morphological differences whatever, in any stage of development. There are, however, definite differences in colour or markings in every stage, and these make recognition of the species a simple matter.



Fig. 27. *Cryptognatha simillima*, adult ($\times 21$).

Description of Stages.

Egg.—The egg is similar in shape and size to that of *C. nodiceps*, but is noticeably more elongate (fig. 14, b). The colour is translucent yellow, and is quite distinct from that of *C. nodiceps*. The chorion is similar, but differs in the reticulation (fig. 15, b), which consists, as in *C. nodiceps*, of paired dots or thickenings arranged in rows, but in *C. simillima* the dots are larger, relative to the size of the mesh, so that the lines look a little thicker. And whereas in *C. nodiceps* there are no dots within the meshes, in *C. simillima* there are several dots in nearly every mesh, which tend to make the network less obvious. The length of the egg varies from 0.46 mm. to 0.51 mm., the average length being 0.48 mm.

First instar larva (fig. 28).—The newly-hatched larva is slightly larger than that of *C. nodiceps*, its average length being 0.68 mm. In colour it is a dull brownish-green, the head being rather darker than the body. The colour is always quite different from that of *C. nodiceps*, for even when the young larva begins feeding and thereby acquires a yellow tinge it is always much darker than *C. nodiceps*. The chaetotaxy is identical with that of *C. nodiceps* except in one detail, namely, that the lateral setae on segments 2, 3, and 11 of *C. simillima* are not markedly longer than those on the succeeding segments.

Full-grown larva.—The colour differences already noted for the young larvae of these two species apply equally to the full-grown larvae; and although they are almost covered with waxy tufts the intersegmental areas are sufficiently devoid of wax to make the species recognisable by its body colour. In every other respect, including even the most minute details of the chaetotaxy, the full-grown larvae of the two species are absolutely identical. The small differences in the setae of the

1st instar larvae do not occur in the later instars. The difference in colour is therefore most important as the only means of distinguishing the species. *C. nodiceps* is always yellow, but *C. simillima*, although varying considerably in colour, is never yellow. For a day or two after each moult the colour is dark green or brown, but towards the end of each instar it becomes much lighter and varies from pinkish brown to greenish brown.

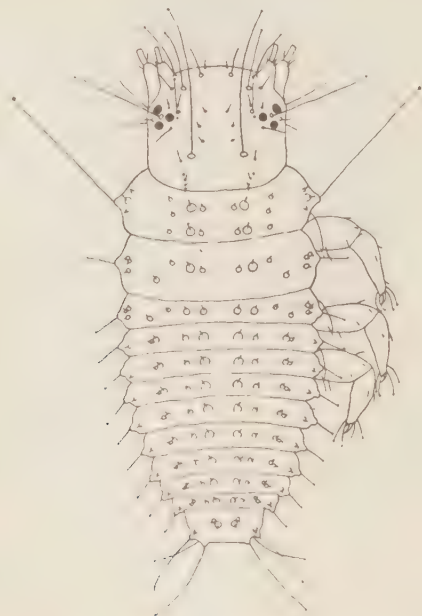


Fig. 28. *Cryptognatha simillima*, 1st instar larva, dorsal view ($\times 90$).

Pupa (fig. 29).—The pupa is appreciably larger than that of *C. nodiceps*, its length being, on the average, 2.85 mm. The greater size is due mainly to the greater length, as the width is not correspondingly greater. The ratio of length to width is 7.3 : 5. The pupa is shiny and very strongly chitinised. Its general colour is very dark brown, approaching black, and there is a narrow brownish-yellow stripe down the centre of the thorax and a broad band of the same colour down the middle of the abdomen. With the exception of this stripe and band, and the sutures of the thoracic region, the pupa is entirely dark brown dorsally and laterally. The exact form of the markings is clearly shown in fig. 29. This coloration is entirely different from that of *C. nodiceps*, and the two species are therefore very readily distinguished in the pupal stage, but the tubercles and setae are absolutely identical. There is considerable variation in the depth of the colour, some pupae being black and others comparatively light.

Adult Variation.—The size and shape of the black spots on the adult are subject to slight variation, but no variation comparable to that of *C. nodiceps* occurs in this species.

Life-history.

The life-history is almost identical with that of *C. nodiceps*, the only differences being in the colour changes which the eggs undergo and in the sites chosen for pupation. In every other respect the account of the habits of *C. nodiceps* applies, word for word, to *C. simillima* also.

When ready to pupate the larvae usually take up positions on the undersides of the leaflets instead of withdrawing to the bases of the main stems of the leaves as do those of *C. nodiceps*.

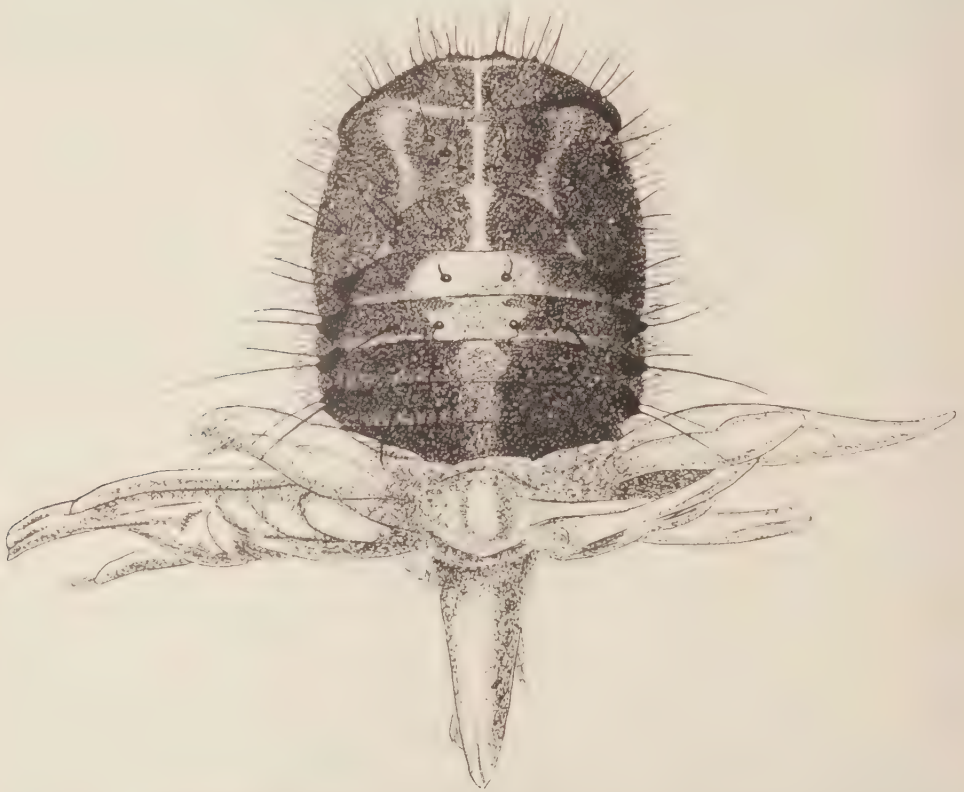


Fig. 29. *Cryptognatha similima*, pupa, with larval skin and waxy tufts *in situ* (\times about 29).

The life-cycle was worked out in Fiji at the same time and in the same conditions as that of *C. nodiceps*. The following results were obtained:—Incubation $6\frac{1}{2}$ – $7\frac{1}{2}$ days, 1st instar $3\frac{1}{2}$ – $4\frac{1}{2}$ days, 2nd $2\frac{1}{2}$ – $3\frac{1}{2}$ days, 3rd $2\frac{1}{2}$ – $3\frac{1}{2}$ days, 4th 6 – $7\frac{1}{2}$ days, pupa $4\frac{1}{2}$ – $5\frac{1}{2}$ days; total 28–30 days. Thus the rate of development is considerably slower than that of *C. nodiceps*, every stage being, on the average, slightly longer.

3. *Azya trinitatis*, Mshl.

Azya trinitatis was found to be very generally distributed throughout Trinidad. It was abundant wherever *Aspidiotus* was abundant, and was always found in small numbers even in those localities where the scale was scarce. It multiplies enormously on trees which are heavily infested with *Aspidiotus destructor* and on such trees it feeds on no other species of scale; but there is considerable evidence indicating that it does not ordinarily confine itself to *A. destructor* to the same extent as do the two species of *Cryptognatha*.

Description of Stages.

Egg.—The egg is of the same shape as that of *C. nodiceps*, but considerably larger. Its colour is yellow. The surface is finely reticulated like that of *C. nodiceps*, but the meshes are rather smaller and therefore more numerous. The minute ultimate

thickenings of the chorion, which constitute the individual lines in the network, are very irregular in shape and far more numerous than in *C. nodiceps*. They are massed together so as to form almost continuous linear thickenings bounding each mesh (fig. 15, c).

First instar larva. The young larva is pale bluish-green, acquiring a yellow tinge after it has started feeding. It is of the usual Coccinellid form, but its colour and form are almost entirely hidden by the wisps and tufts of white wax with which it is entirely covered dorsally and laterally, and which develop rapidly within a few hours after it leaves the egg. Even when newly-hatched the larva is quite conspicuous on the leaf as a white dot on account of the density of the waxy covering. The arrangement of the waxy tufts is the same as that described below for the full-grown larva.

Full-grown larva (figs. 30, 31).—The body of the full-grown larva is scarcely perceptible on account of the waxy tufts, but when these are removed the body

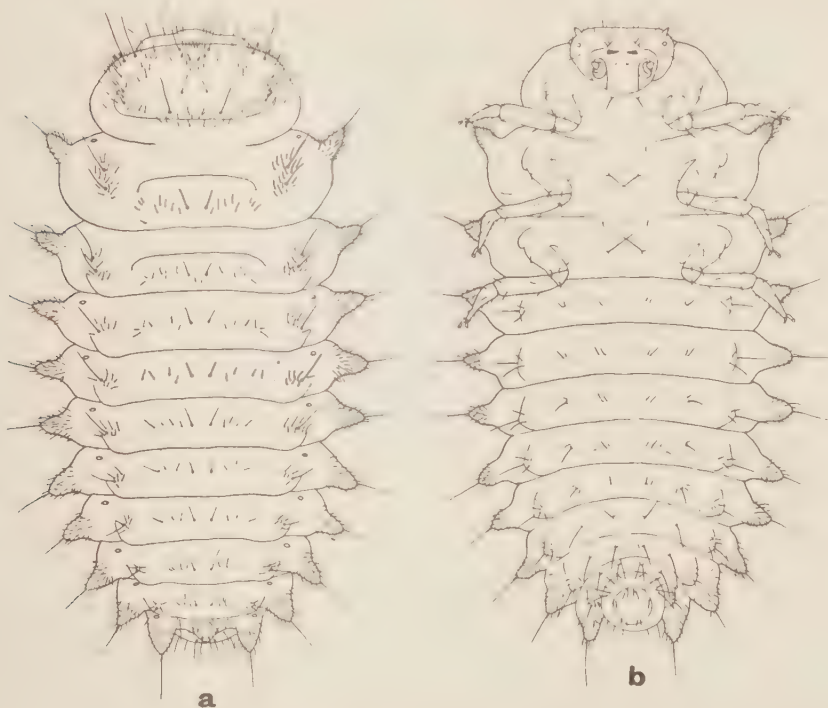


Fig. 30. *Azya trinitatis*, full-grown larva ($\times 22.5$): a, dorsal view; b, ventral view.

is seen to be a pale, dull, brownish-yellow colour throughout. At a glance the larva with its tufts looks like a large mealy-bug, the resemblance being stronger than in the case of *Cryptognatha* because the body is more rounded. The body is, in fact, broader than in most Coccinellid larvae, and when the tufts become matted together, as they often do by contact with various obstacles on the leaves, the resemblance to a mealy-bug is particularly marked.

The body is widest in the centre (*i.e.*, at segments 4 and 5), and its greatest width is equal to, or a little greater than, its length. There are 13 segments, and the segmentation is very evident on account of the prominence of the lateral tubercles. The thoracic segments are longer than the abdominal. Only 11 segments are wholly

visible dorsally, the 12th being partly retractile into the ventral side of the 11th, and the 13th, which is button-like and prehensile, is totally retractile into the 12th.

The body is entirely without markings, and although it bears many setae it is not noticeably hairy, the setae being short and insignificant. The most noticeable feature is the complete lack of tubercles on the 1st segment, which is transversely grooved across its dorsal surface, the posterior slope of the groove being very steep and its anterior slope gradual. Many setae arise from the posterior slope and from the bottom of the groove, most of which are minute, but there is a pair of dominant, relatively long setae near the middle line, and three dominant setae at either end of the groove. The anterior edge of this segment bears many minute setae distributed as in the figure; in addition there are two dominant pairs of setae near the middle line and two similar setae at each antero-lateral corner.

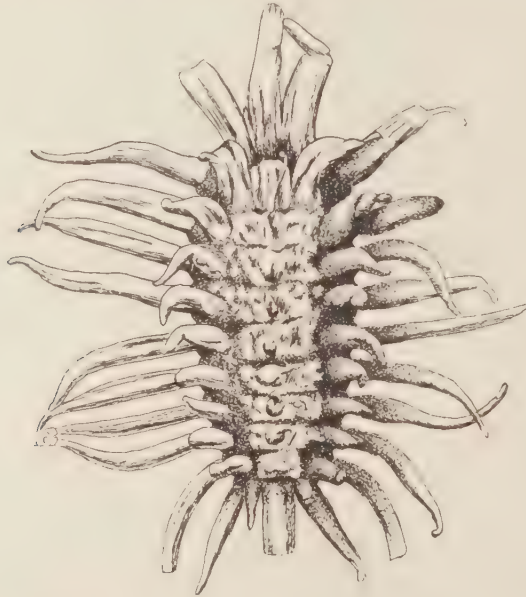


Fig. 31. *Azya trinitatis*, full-grown larva, normal appearance with waxy tufts.

Segment 2 is also grooved transversely across the back, but in this case the anterior slope is the steeper. The prominent lateral tubercles bear many minute setae which are distributed all over them, and a single, relatively long, terminal seta. Just inside the spiracular line there is a dorso-lateral group of about 20 setae, of which two are long and the rest minute. A pair of dorsal, relatively long setae arises near the middle line and behind the groove, and an irregular row of minute setae extends outwards on either side from this dorsal pair towards the dorso-lateral group of setae, without, however, reaching them. Segment 3 is identical in all these respects with 2, except that the small setae are rather less numerous. Segments 4-10 are very similar to segments 2 and 3 in their chaetotaxy, except that in each of them there is only one dominant seta in the dorso-lateral group and that there are fewer minute setae on the more posterior segments as far as, and including, segment 9; on segment 10 they are very numerous.

Apart from the lateral tubercles, there are no tubercles on any segments, except the 11th. The dorso-lateral groups of setae are mounted on slight convexities of the surface, but these can scarcely be termed tubercles, though they are certainly homologous with the dorso-lateral tubercles of other species. The 11th segment,

however, bears, in addition to the lateral tubercles which are directed backwards, a median dorsal tubercle which is also directed backwards. This tubercle gives rise to the dorsal pair of dominant setae as well as many small setae. The 12th segment is entirely different from all those which precede it. It is annular in form and bears no tubercles, though several pairs of rather long setae arise from it, the most conspicuous being the dorsal pair. Only a small part of this segment is visible dorsally.

A pair of spiracles is present on all the segments except the 1st, 3rd, 12th, and 13th. There are no intersegmental pores in this species, which is therefore incapable of producing a repellent fluid. It is noteworthy that this larva is entirely devoid of microtrichia, and that none of its setae is knobbed.

The ventral surface bears a few setae, arranged as in fig. 30, **b**. The legs are comparatively long and slender, the setae being the same on all of them. At the extremity of the terminal segment there is a single, long, stout, trumpet-like seta which projects beyond the tip of the claw.

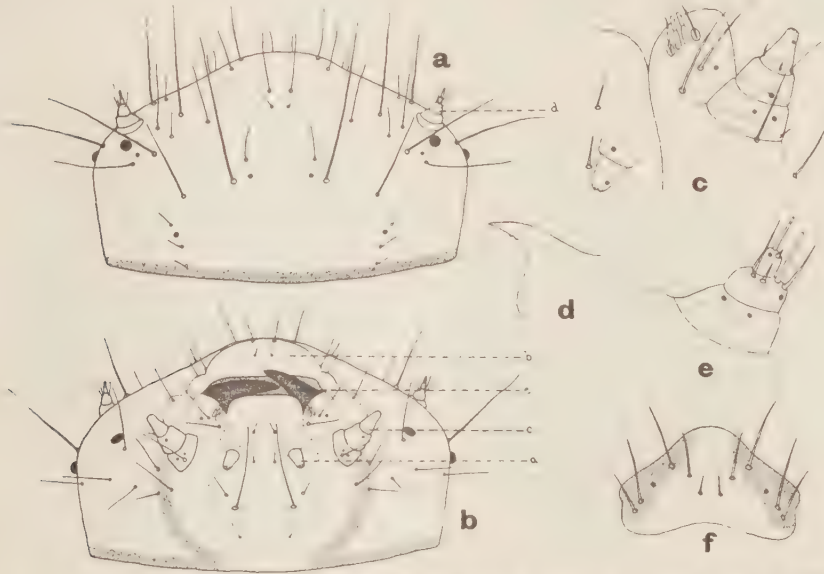


Fig. 32. *Asya tremulata*, head-capsule of full-grown larva: **a**, dorsal view ($\times 90$); **b**, ventral view ($\times 90$); **c**, portion of labium and maxilla to show palpi ($\times 150$); **d**, mandible ($\times 100$); **e**, antenna ($\times 225$); **f**, labrum ($\times 100$). (Other lettering as in fig. 18.)

The head is relatively short and broad, and withdrawn beneath the 1st segment when the larva is at rest. The arrangement of the setae, the mouth-parts and antennae, are shown in fig. 32. There are 3 ocelli on either side, but only two are visible dorsally, the third being on the ventro-lateral surface.

The waxy tufts (fig. 31), which cover the body, are arranged in five series, mid-dorsal, and paired dorso-lateral and lateral. These five series are represented on all the segments except the last two, which, being retractile, bear no wax. The lateral tufts are always the longest, and project radially from the body in a plane parallel to the surface on which the larva is resting. The lateral tufts of the 1st segment, which project more forwards than sideways, are thicker than any of the others and often appear to have been cut off squarely with a knife. The mid-dorsal tufts, except on segments 1 to 11 are very short and slim, and are usually twisted. Each of them arises in the centre of its segment and curves forwards. They are frequently

not apparent as distinct tufts because each of them becomes partly incorporated with, and obscured by, a flimsy, irregular tangle of wax which covers the dorsal area of each segment. This mass of wax is separated from that of each adjacent segment by a narrow intersegmental space devoid of wax; and it is more or less rectangular in shape, being bounded on either side by the base of the dorso-lateral tufts. These dorsal waxy patches, of which there are nine altogether and which include the mid-dorsal tufts, together form a prominent broad white band down the back of the larva. The mid-dorsal tufts of the 1st and 11th segments are entirely different from the others of the same series. They are very thick and long, and project respectively forwards and backwards. Dorso-lateral tufts are present on segments 2 to 11 inclusive. Those on segment 11 are small and flimsy, and point backwards. The remainder are short and stout, and their extremities overhang the bases of the lateral tufts. As is always the case, the tufts correspond with and arise from the tubercles or groups of setae. The lateral and dorso-lateral series of *Azya* are clearly homologous with those of a larva such as *C. nodiceps*. The latter type of larva, however, is devoid of mid-dorsal tufts, its paired dorsal tufts being represented in *Azya* by the waxy patches on the back.

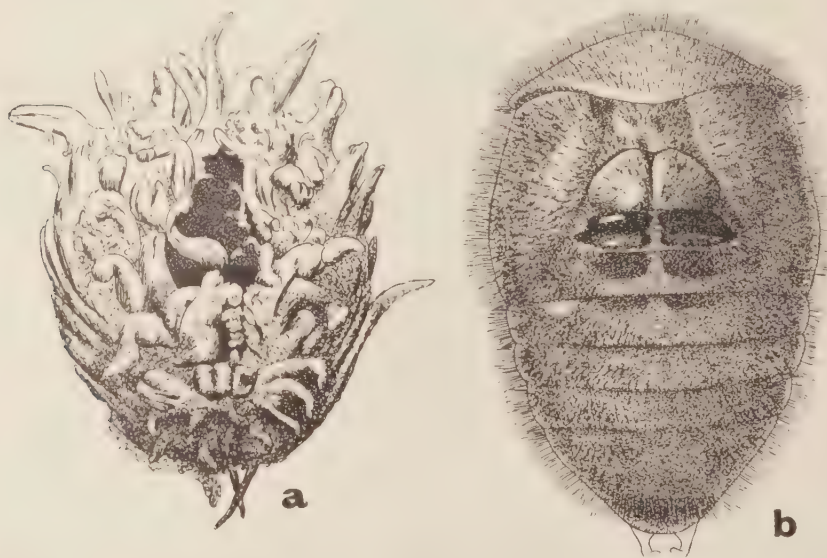


Fig. 33. *Azya trinitatis*, pupa: **a**, with waxy covering; **b**, without waxy covering ($\times 24$).

Pupa (fig. 33).—The pupa retains the waxy covering of the larva and is almost entirely concealed by it. The tufts do not, for the most part, project individually as in the larva, but are wrapped around the pupa and matted together so as to form a thick and irregular, but almost continuous, layer over it. This gives the pupa a very curious and unkempt appearance. In most instances, the wax is not quite continuous over the back but has the appearance of having been torn for a short distance mid-dorsally and drawn apart (fig. 33, **a**). This exposes a small part of the back of the pupa itself in the neighbourhood of the dark brown markings (described hereafter) which show through the gap in the wax. When all the wax has been removed (fig. 33, **b**) the pupa is seen to be shiny and of a dull, translucent, brownish-yellow colour. It is entirely devoid of tubercles or long bristles, but is densely covered, except ventrally, with innumerable short brown hairs of uniform length. There are no markings on the thorax or elytra, but there are a few markings

on the abdomen. These consist of paired dark brown patches, nearly meeting in the middle line, on the first two segments of the abdomen. There is usually a trace of similar markings on the 3rd and 4th abdominal segments also. The hairs are not glandular in this species, and there are no repugnatorial pores. The usual six pairs of spiracles are present, but there is no lobe protecting the first abdominal spiracle. The segmentation of the abdomen is not very distinct, as the cuticle is not strongly chitinated. The average dimensions of the pupa are : Length 2.8 mm., breadth 1.8 mm.

Life-history.

Egg.—The eggs of *A. trinitatis* are never laid inside scales. In this respect it differs from all the other Coccinellids found in association with *Aspidiotus* in Trinidad. Instead, the eggs are laid singly on the leaves, or on other parts of the trees, without any covering. Their orientation is such that their long axes are parallel to the surface of attachment. Being fully exposed they are comparatively easy to see on the leaves.

Larva.—The larval habits are similar to those of *C. nodiceps*, but growth is much slower and the larva is less voracious. There are four larval instars, and therefore three moults. At each moult the waxy tufts are shed with the old skin and new ones develop, but except for 3 or 4 tufts at the hind end, all the wax breaks away from the old skin at the time of moulting, so that the old skin, unlike that of *C. nodiceps*, is nearly naked. This is probably due to the fact that the setae are not knobbed.

When ready to pupate the larva usually affixes itself to the underside of one of the leaflets on which it has been feeding. The process of pupation is remarkable in that although the larval skin is pushed back to the hind end of the pupa, as in *C. nodiceps*, the waxy tufts which cover the skin prior to dehiscence are not carried back with the skin but remain as a covering for the pupa. This waxy covering of the pupa suggests, at first sight, that this species, like many COCCINELLIDAE, retains the larval skin as a covering for the pupa, except for the mid-dorsal split; but careful removal of the wax with a needle shows that the larval skin is thrust back to the hind end and covers only the last few abdominal segments. The means by which the skin is cast without shifting the wax which was formerly attached to it are interesting. When preparing to pupate the larva contracts and becomes hunched up in the usual way. This brings the tufts of each segment in contact with those of adjacent segments, and those which are in contact adhere to one another so that a continuous layer of tangled tufts is produced. This layer is not firmly attached to the skin because the larval setae, being comparatively short and without knobs, are not firmly embedded in the wax, as are those of *C. nodiceps*. Thus, when the skin splits mid-dorsally and is worked back, the tufts adhere more strongly to one another than to the old skin, and the wax remains as a covering for the pupa, except for the small gap in the middle of the back.

Pupa.—The waxy covering of the pupa is held in place by the fine hairs which are distributed all over the body, but it rests on the tips of the hairs only and is nowhere in contact with the body of the pupa. There is therefore an air space between the skin of the pupa and the waxy covering, which is scarcely disturbed by the act of pupation, and therefore the pupa has almost exactly the same appearance as the prepupa. The pupa itself is incapable of producing wax, and does not emit a repellent fluid when disturbed.

Adult.—The adult emerges by splitting the pupal skin down each side. No dorsal split occurs except in the pronotum. Since the pupal skin is scarcely disturbed at all dorsally the waxy covering retains its original position after the emergence of the adult, and in most cases it is difficult to tell at a glance whether the adult has emerged. The adult remains underneath the pupal skin while its cuticle is hardening and the permanent colour is developing. It does not move away to begin feeding

until the day after emergence. Its habits are the same as those of *C. nodiceps*, except that all its activities are slower.

Life-cycle.—This was worked out in Fiji in June and was found to be as follows :—Incubation 8–9 days, 1st instar 4 days, 2nd 4–6 days, 3rd 4–7 days, 4th 8–12 days, pupa 5–7 days; total 34–39 days. The rate of development is therefore much slower than that of *C. nodiceps*.

4. *Pentilia insidiosa*, Muls.

This species was found to be common and widely distributed in Trinidad, but was not nearly so abundant as *C. nodiceps*. In general, its habits are the same as those of *C. nodiceps*. No detailed study of it was made.

The egg is light yellowish-green in colour and of the usual Coccinellid form, and turns almost black on the day before it hatches. It is laid inside empty scales.

The larva is of a dark brownish-green colour, sometimes approaching black, and is therefore quite different from all the other species found in association with *Aspidiotus* in Trinidad. In shape it is oval and flattened, and there is no marked tapering towards the posterior end. In all instars except the 1st it bears long thin waxy tufts which radiate from its middle point in a plane parallel to the surface on which it is resting. These tufts originate laterally, and are homologous with the lateral series described for *C. nodiceps*, etc. The back is thinly dusted all over with white particles of wax, but there are no definite tufts, other than the lateral series, except on the first segment, which has a pair of stout tufts projecting forwards over the head, and on the last dorsally-visible abdominal segment which has a short stout tuft projecting backwards like a tail.

This species differs from the other Trinidad species described herein in that no waxy tufts are formed in the 1st instar, but this is not unusual. The tufts of *P. insidiosa* are each supported on a long seta. There are no other long setae on the body, but the back bears a very few short ones. All the setae are white and show up clearly against the dark body.

The mode of pupation of this species is similar to that of *C. nodiceps*, the old larval skin being thrust to the hind end, but the tufts are arranged radially, though rather irregularly, all round the pupa.

The complete life-cycle was not determined, but the duration of the incubation period was found to be 7–8 days, and the pupal period 4 days.

5. *Scymnus aeneipennis*, Sic.

Scymnus aeneipennis was found commonly in Trinidad wherever *Aspidiotus destructor* was sufficiently plentiful to constitute an outbreak. It was also found in localities where the scale was rare. It is easily distinguished, in all stages except the egg, from all the other species found in association with *A. destructor* in Trinidad.

Description of Stages.

Egg.—The egg is translucent greenish-yellow. In size it is nearly the same as that of *C. nodiceps* and *C. simillima*, despite the much smaller size of the adult. Its shape is nearer that of *C. nodiceps* than that of *C. simillima*. The average dimensions of 20 eggs were found to be :—Length 0.52 mm., width 0.26 mm. The egg-shell is very finely reticulated, the meshes being a little smaller and less regular than those of *C. nodiceps* or *C. simillima*. The network is formed of double rows of dots, as in the two latter species. There are no dots within the meshes. Since the egg is laid in the

same situations as those of the two species of *Cryptognatha*, it is often difficult to identify it with certainty. But with practice the colour differences usually serve to distinguish the species, this species being intermediate in colour between *C. nodiceps* and *C. simillima*.

First instar larva (figs. 34, 35).—The newly-hatched larva, prior to the commencement of feeding is larger than that of either *C. nodiceps* or *C. simillima*, its average length being 0.71 mm. Its colour is pale yellowish-green. There are three pairs of vaguely defined dark spots on the dorsal surface, one pair on the 1st segment, one pair on the 4th segment, and one pair, which is fainter than the others, on the 9th and 10th segments. There are 13 well-defined segments, of which the last is small and button-like and is concealed under the 12th. The greatest width of the body is at the 3rd segment. The first three segments are much longer than the others except the 12th.

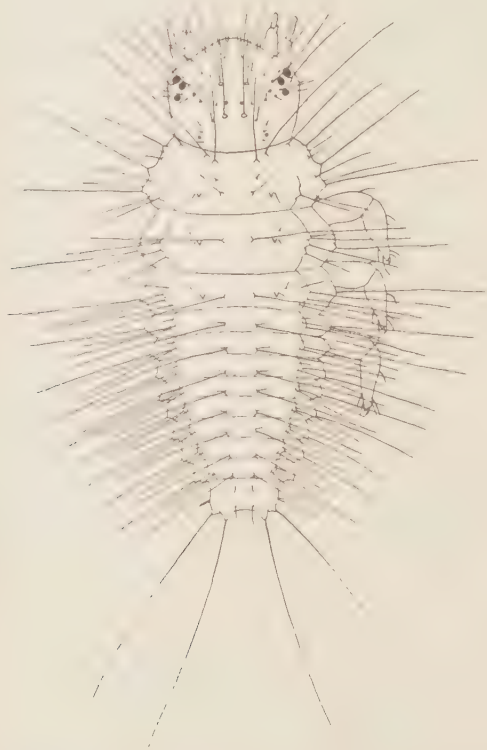


Fig. 34. *Scymnus aeneipennis*, 1st instar larva, dorsal view ($\times 90$).

The body bears a large number of very long setae which give it a very hairy appearance. The setae are arranged, for the most part, in the usual three longitudinal rows on either side. The two dorsal rows are near the middle line, and each is represented on every segment from the 1st to the 12th inclusive by a single seta. The dorsal pair of setae on the 1st and 12th segments are short, but all the others are very long. At the base of each of the dorsal setae on the abdominal segments there is a single very short seta. The dorso-lateral series is represented on each of the abdominal

segments except the last two by a group of three setae mounted close together on a large tubercle, two of which are long, and the other very short. The thoracic segments are similar to the abdominal as regards the dorso-lateral setae, but there is on the 1st segment only one seta which definitely belongs to this series, while on the 2nd and 3rd segments there are four setae on the dorso-lateral tubercles instead of three. The setae in the lateral row, which are mounted on prominent tubercles, are all very long, but decrease in length posteriorly. There is only one lateral seta on every segment. The 1st segment possesses far more setae than any of the others. All the additional setae are situated near the anterior and lateral borders of the segment and are arranged as in fig. 34. The 12th segment has fewer setae than any of the others, but on either side it bears postero-laterally two exceptionally long setae mounted on separate but adjacent tubercles and directed backwards. It is probable that the inner of these is homologous with the dorso-lateral setae of the other segments and the outer with the lateral setae. On each of the first three segments, between the dorsal and dorso-lateral setae, there is a minute chitinous tooth with a very small seta beside it. There is another similar seta a short distance from it. None of the setae is knobbed. The ventral surface bears a few very fine setae arranged as in fig. 35. The body is covered all over its surface with microtrichia.

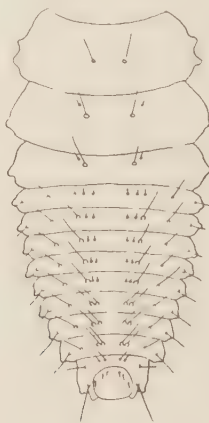


Fig. 35. *Scymnus aeneipennis*, 1st instar larva, ventral view (head and legs omitted) ($\times 90$).

The head (fig. 34) bears many setae, some of which are very long, and is considerably broader at the level of the ocelli than at its posterior end. This larva is incapable of producing waxy tufts at any stage of its growth.

Full-grown larva (figs. 36, 37).—The colour of the full-grown larva is deep rich yellow. There are a number of brown markings, not very sharply outlined, as shown in fig. 37. Of these only the larger or more isolated markings are apparent at a glance, with the result that the larva appears to have three pairs of spots, one at the anterior end, one a little in front of the middle, and one near the hind end. The spots on the 1st segment are small, and occupy depressions in the surface. The second pair of spots is situated chiefly on the 4th segment, just outside the dorsal tubercles of that segment and extending over the dorso-laterals, but it also extends forwards on to the 3rd segment. The third pair of spots is on segments 9 and 10 and occupies the same position, relative to the tubercles, as the second pair. On each of the segments 5, 6, 7 and 8 there is a small pigmented area between the dorsal and dorso-lateral tubercles. These areas together form a faint brown stripe down each side connecting the 2nd and

3rd pairs of spots. The pigmented areas are very distinct at the beginning of the last instar, but when the larva is full-grown they are very faint. The length of the full-grown larva varies from 2·7 mm. to 3·4 mm.

The segmentation is exceptionally distinct, and there are 13 segments, of which the last is retractile into the 12th. The greatest width of the body is at the 5th and 6th segments. The first segment has two pairs of very prominent tubercles, each bearing many long setae, of which one is longer than any of the others. The dark colour of the two depressions is due to extra chitinisation of the integument. Several short setae arise from their posterior edges. All the segments from the 2nd

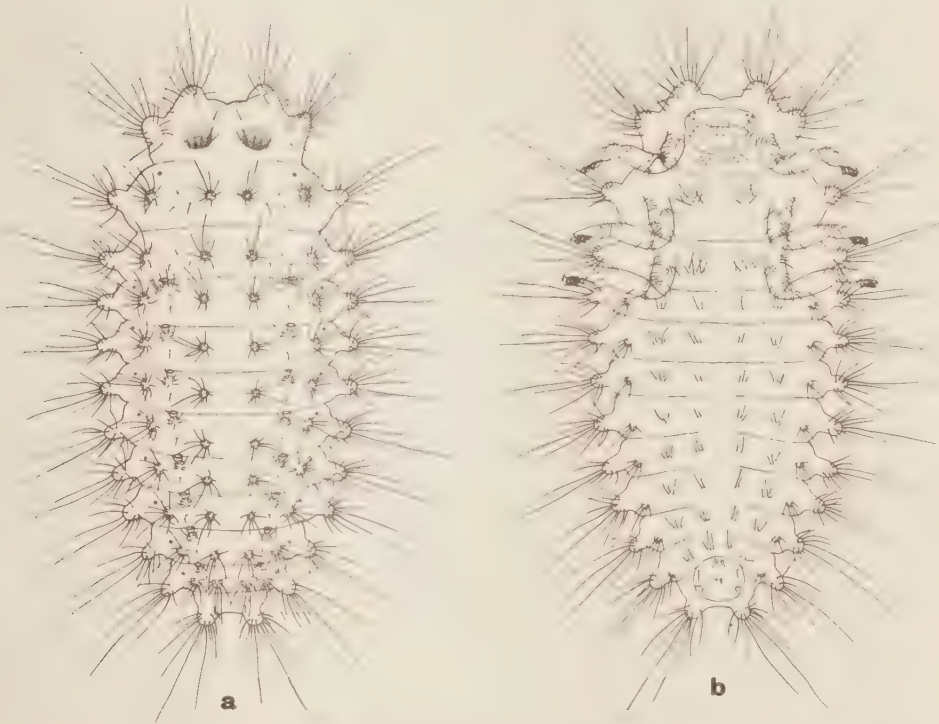


Fig. 36. *Scymnus acneipennis*, full-grown larva (\times about 23) : **a**, dorsal view ; **b**, ventral view.

to the 11th inclusive possess three pairs of prominent tubercles, each of which bears numerous long, stout setae of different lengths, one being terminal and dominant. The lateral setae are longer than the others. The dominant setae on the lateral tubercles are transparent, colourless, and flexible ; all the other setae, dominant and otherwise, are very strongly chitinised, relatively thick, dark brown, and not flexible. Segments 2 and 3 each bear three separate setae between the dorsal and dorso-lateral tubercles. Segments 4 to 11 bear an additional tubercle, less prominent than the others, situated between and in front of the dorsal and dorso-lateral tubercles. Just in front of this tubercle is an intersegmental pore, from which the larva emits a repellent fluid when disturbed, and these tubercles bear a number of short setae, most of which

are directed forwards so as to overhang the pore. The first tubercle of this series (*i.e.*, on segment 4) is larger and bears more setae than any of the others, and directly behind each tubercle is a single short seta not associated with any of the tubercles. Segment 12 bears only one pair of tubercles. These are large, prominent, and directed backwards, and resemble the lateral tubercles in all respects.

There are 9 pairs of spiracles in the usual positions, and 8 pairs of intersegmental pores. The whole surface of the body, except in the depressions on the 1st segment, is densely and uniformly covered with microtrichia. The ventral surface (fig. 36, **b**) bears numerous setae, but all of them are thin and inconspicuous. The legs bear many setae, and the chaetotaxy of all of them is the same. The most striking feature of the legs is an unusually large group of setae with swollen extremities, situated at the distal end of the terminal segment.

The head (fig. 38) is completely hidden under the 1st segment when the larva is at rest, and bears many setae, some of which are abnormally long. There are no markings or sutures visible on the dorsal surface, but ventrally some of the sutures separating the sclerites of the mouth-parts are apparent.

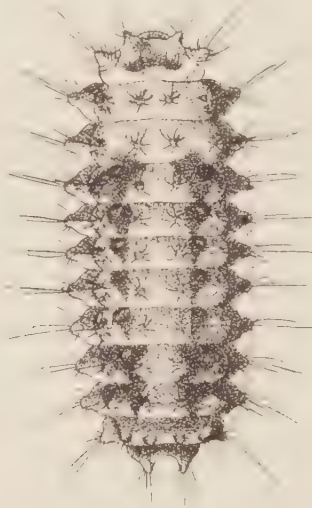


Fig. 37. *Scymnus aeneipennis*, full-grown larva ($\times 20$)

Pupa (figs. 39, 40).—The pupa is of a rich amber-yellow colour. The abdomen is lighter than the wing-cases and thorax. The only markings consist of two prominent, dark brown spots on the mesothorax. The pupa is entirely covered, except ventrally, with a white pubescence. On the abdomen this is very sparse, short and scarcely perceptible, but elsewhere, and especially at the anterior end, it is very dense; the individual hairs are all short and of uniform length, and those on the wing-cases are all curved backwards at their extremities. There are no prominent tubercles.

The pupa bears numerous short setae arranged as in fig. 40. The general arrangement of those on the thorax is constant, but those which are grouped together vary slightly in number and position. There is only one pair of setae on the mesothorax. The metathorax bears one pair of dominant dorsal setae, and another pair of setae just behind the dominant ones; and there is also a dorsal-lateral pair. The 1st abdominal segment bears a single pair of dorsal setae, and no others. Each of the

next four abdominal segments bears a single pair of dorsal setae, and two lateral setae on either side. The 6th abdominal segment has a pair of dorsal setae but no lateral ones. There are no dorsal-lateral setae on any of the abdominal segments, and the last three segments, which are normally covered by the old larval skin, are entirely devoid of setae.

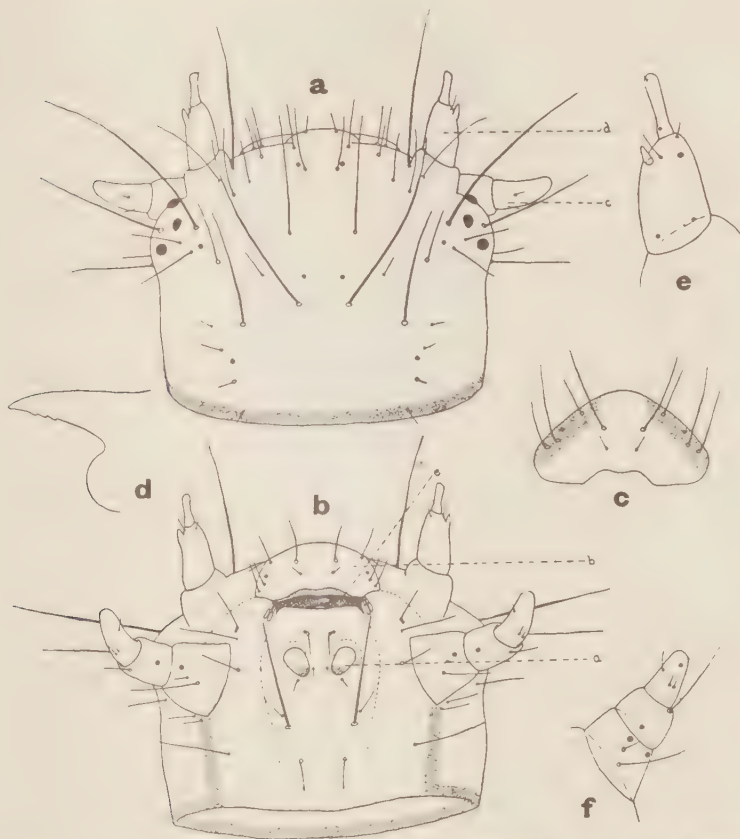


Fig. 38. *Scymnus acutipennis*, head-capsule of full-grown larva: **a**, dorsal view ($\times 137.5$); **b**, ventral view ($\times 137.5$); **c**, labrum ($\times 150$); **d**, mandible ($\times 250$); **e**, antenna ($\times 250$); **f**, maxillary palp ($\times 150$). (Other lettering as in fig. 18.)

There are 6 pairs of spiracles. The 1st abdominal tergite has a pair of small chitinous lobes at its antero-lateral corners, and these overhang the spiracles of that segment. There are no repugnatorial pores in the pupa, although these are present in the larva. All the setae are glandular and produce minute drops of clear fluid which remain attached to their extremities; the pubescence is not glandular. The cuticle of the pupa is comparatively flimsy. The dorsal tergites, therefore, are not clearly marked. The average length is 2.20 mm.

Life-history.

Egg.—The eggs are laid singly under scales, in exactly the same manner as those of *C. nodiceps*. Very rarely they are found free on the leaves.

Larva.—The habits of the larva are identical with those of *C. nodiceps*, except that it produces no wax. There are four larval instars.

Pupa.—Pupation is effected by thrusting the old larval skin to the hind end, where it remains. The old skin always covers the last three abdominal segments of the pupa

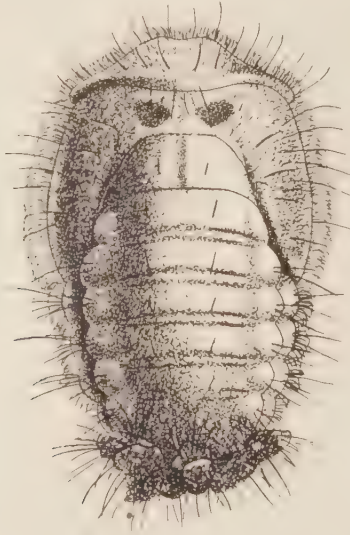


Fig. 39. *Scymnus aeneipennis*, pupa, normal appearance with larval skin *in situ* (\times about 27).

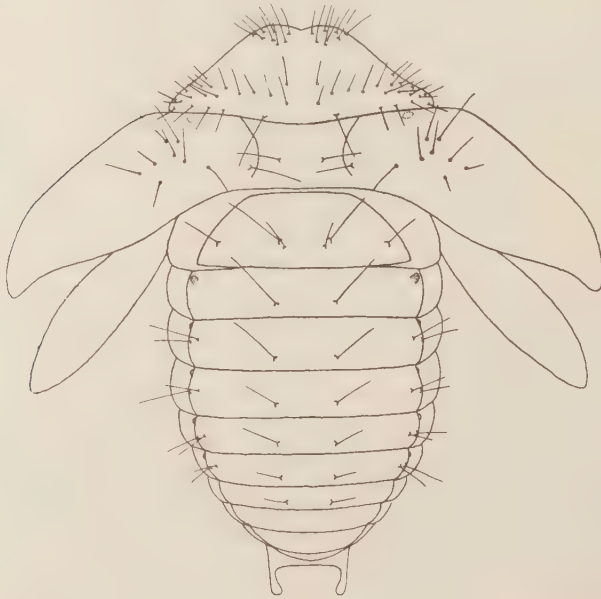


Fig. 40. *Scymnus aeneipennis*, pupa, showing chaetotaxy (\times 32.5).

entirely, and also the sides, but not the back, of the preceding segment; hence the absence of lateral setae on the 6th abdominal segment and of all setae on the succeeding

segments. This position of the larval skin, relative to the abdominal segments, is absolutely constant.

Adult.—The adult remains under the pupal skin until the day after emergence. Its habits are the same as those of *C. nodiceps*, except that it is much less voracious. The duration of the adult life is at least 6 weeks.

Life-cycle.—This was worked out in Fiji in May 1928, and was found to be as follows:—Incubation 6-7 days, 1st instar 5-6 days, 2nd 4-6 days, 3rd 4-5 days, 4th 6-7 days, pupa 5 days; total 31-35 days. The rate of development is therefore considerably slower than that of *C. nodiceps*.

VII. IMPORTATION OF NATURAL ENEMIES FROM JAVA.

In 1926 it was decided to ship to Fiji the following Javan parasites and predators as soon as a suitable opportunity offered:—*Aphelinus chrysomphali*, Mercet, *Comperiella unifasciata*, Ishii, *Spaniopterus crucifer*, Gahan, *Casca parvipennis*, Gahan, *Scymnus* sp. and *Aleurodothrips fasciapennis*, Frankl.

The length of the voyage and the desirability of obtaining a direct steamer presented some difficulties, but towards the end of 1926 arrangements were made for a direct coolie steamer, s.s. "Ganges," which was due to leave India for Fiji in December, calling at Tanjong Priok, Java, en route. The transport of the scale parasites was not the main object of the voyage, but it was thought wise to take the opportunity of getting some of the Javan scale parasites to Fiji and experimenting with them there. The ship arrived at Tanjong Priok on 1st January, 1927, and the six species of parasites and predators were shipped on the following morning, the steamer sailing immediately for Fiji direct. The "Ganges" arrived off Suva, Fiji, on 21st January, 19 days out from Java. A severe outbreak of smallpox on the ship led to many difficulties, as the shipment could not be landed at Suva, but had to go, with all on board, to the quarantine island of Nukulau. It was necessary to extend the quarantine period to 5 weeks, and it was most difficult to keep the insects going for this additional period without proper facilities. Nukulau is a very small coral islet 7 miles from Suva. It has a few coconut palms, some of which were slightly attacked by *Aspidiotus destructor* at the time, but the scale supply was very limited, and the island was most unsuitable for making the first liberations of natural enemies. It was found possible to get a few colonies through to Suva by launch without incurring any risk of spreading the disease, but many liberations had to be made on the island, in the hope that the insects could be recovered later.

1. Methods of Shipment and Bulk Breeding.

The method adopted for dealing with the parasites on board ship was very simple, as they were found to breed satisfactorily in captivity. The method consisted in enclosing large numbers of the parasites in large wooden cages (6 ft. high by 3 ft. by 3 ft.) containing young coconut palms infested with *Aspidiotus destructor*. The palms were prepared a month before the sailing date. They were planted in kerosene tins, and were infested with scale by pinning infected leaflets on the undersides of their leaves. The scale employed was in such a stage that the eggs were beginning to hatch. It is obviously useless to employ scale in any other stage for this purpose, because the leaflets die as soon as they are cut and the scale on them dies soon afterwards. The most suitable young palms for shipment are those which are about 4 ft. high and have broad leaves which have not yet split into leaflets. Fifty infested

palms of this type were shipped on the "Ganges." Ten cages were shipped. The upper half of each cage was merely a framework with white cloth stretched across each side and the top, so that there was good illumination inside. All the species bred satisfactorily on the ship in these cages.

Much of the scale on the palms used for shipment was caused to be parasitised in Java, so that the parasites were available in all stages of development at all times during the voyage. As soon as each batch of adults emerged in any cage a fresh scale-infested palm was put in and in this way breeding was maintained almost continuously, and all stages of the parasites were landed in Fiji. Since no true secondary parasites were found in Java, it was unlikely that any would appear on the voyage, and none did appear, but it was necessary to eliminate from certain cages those species, notably *Casca parvipennis*, which are normally primary but often secondary also.

The greatest difficulty met with on the voyage arose through more than one species of primary parasite being present in the same cage, for the precautions taken to ensure that a pure culture of one species only was present in each cage proved insufficient. Large numbers of *Aphelinus chrysomphali* appeared in the cages which were intended to contain *Comperiella unifasciata* and oviposited in the available scale, so that the amount of scale available for *Comperiella* was greatly diminished. This difficulty was not a matter of hyperparasitism, but simply the competition for the available food supply, and in some cases of multiparasitism, the external parasite frequently destroying scales containing the internal parasite. It was necessary to devote hours every day to the destruction of all parasites in each cage except those required.

These complications did not arise during the preliminary breeding experiments in Java, presumably because the parasites were not so crowded in the cages. The importance of isolating each species completely cannot, however, be too strongly emphasized, and if other shipments of this nature are made in the future complete isolation must be attained by isolating the palms from the very beginning, so that no parasites can attack the scale on them prematurely.

During the last half of the voyage many batches of scale containing pupae of the parasites were cut from the palms and put in cold storage on the ship. The temperature in the cold chamber varied greatly, but averaged about 62°F. The pupal stage was satisfactorily lengthened in this way, but it was considered unwise to rely much on the cold storage method.

For the purpose of bulk breeding ashore, the cages were used in exactly the same way as on the ship.

The predators were bred in the cages in the same manner as the parasites, and without any difficulty.

2. Parasites.

All the parasites shipped in Java were landed at Nukulau in good numbers on 21st January 1927. On account of the prospect of a long period of quarantine, and the lack on the island of young palms with scale in the right stage for the attack of the parasites, it was deemed necessary to liberate most of the parasites at once on the island, retaining a few with which to infect the small amount of scale which was then left on the Java palms. The few well-grown palms on the island had some scale on them, and it was hoped that the parasites could be recovered from them later.

All the species of parasites continued breeding in small numbers in captivity throughout the five weeks of quarantine, and it was possible at the end of this time to take a few of them to Suva, where attempts to breed them in bulk were then begun. Many unforeseen difficulties, none of which were experienced in Java, arose at this

point. Firstly, the scale with which the young local palms had been infested produced almost entirely male progeny;* consequently, the scale supply did not steadily increase as it should have done, and most of the parasites refused to oviposit. Secondly, the internal parasites showed a marked reluctance to attack the Fiji scale even when it was in the right stage, although they attacked the scale on the Java palms in Fiji with avidity. No morphological differences in the Fiji and Javan scales could be detected, and the differences, whatever they may be, must be physiological. Not only did the parasites exhibit reluctance to oviposit in the Fiji scales, but also many of the scales in which they appeared to oviposit failed to yield parasites, and many of those parasites which did succeed in developing to some extent inside the scales died as larvae. The result was that the percentage of parasitised scales in any batch was very small, whereas in Java a parasitism of 90 per cent. was obtained without difficulty. A very similar experience has been recorded by Compere and Smith in California, where *Comperiella bifasciata* failed to propagate in the *Chrysomphalus aurantii* which occurs there, although that scale is its most common host in China and Japan, whence the parasites were imported into California. The third difficulty met with in Fiji was that on many of the young palms nearly all the scale would suddenly die off, usually during the 2nd instar. The cause of death was not apparent. For this reason, and others, it became very difficult to provide the parasites with scale in the stage attacked by them whenever they required it.

The attempts made to recover the parasites at Nukulau were equally disappointing, for although a few scales parasitised by them were found, they were not sufficiently numerous to relieve the situation.

In consequence of all these difficulties very few colonies of the parasites were liberated. The only species which was bred continuously in Fiji for any length of time was *Spaniopterus crucifer*, but even in this case it was found impossible to obtain large numbers of it, and the work was abandoned at the end of August 1927. The following liberations were made:—

Aphelinus chrysomphali.†

250 at Nukulau. Jan. 1927.

Comperiella unifasciata.

90 at Nukulau. Jan. and Feb. 1927.

14 „ Nasese (Suva). March 1927.

Spaniopterus crucifer.

About 1,000 at Nukulau. Jan. and Feb. 1927.

„ 50 „ Nasese (Suva). Jan. 1927.

„ 60 „ „ March 1927.

„ 250 „ Naigani. Aug. 1927.

Casca parvipennis.

About 1,000 at Nukulau. Jan. and Feb. 1927.

No satisfactory recoveries of the descendants of these parasites were ever made. All four species were recovered at Nukulau one month after they had been liberated, and certainly went through one generation in small numbers, but they have never been found since, there or elsewhere. It is very doubtful whether any of them became established in Fiji, especially in view of the fact that the Coccinellid beetles which were imported from Trinidad in 1928 spread and multiplied with amazing rapidity and caused the scale to become extremely rare in all localities soon afterwards.

* This is a common occurrence with many species of scale, but it does not occur more frequently in the field in Fiji than elsewhere.

† The imported individuals of this species were subsequently found to be identical with the *Aphelinus* which was already present in Fiji.

3. Predators.

The two predators, *Scymnus* sp., and *Aleurodothrips fasciapennis*, bred extremely well in their cages, and no difficulty was experienced in breeding them in Fiji as soon as a good supply of scale on small palms became available. The work on the thrips was, however, abandoned, as this, or a closely allied, species was found to be present, though rare, in Fiji already.

Scymnus sp. was bred in bulk from January to December 1927, and distributed to all the islands where the scale was found. About 4,000 individuals were liberated in the year. Nearly every colony consisted of 100 adults, this number being ample for the establishment of the species. This insect (unlike the parasites) showed no distaste for the Fiji scale and flourished in the field in many localities. It certainly became established in Fiji. Colonies were liberated as follows :—

Nukulau ...	...	...	...	...	...	Jan. 1927
Nasese (Suva) ...	...	...	...	...	...	"
Suva ...	...	...	...	...	...	March 1927
Kadavu (2 colonies) ...	...	...	...	...	...	July 1927
Koro ...	...	...	...	...	...	"
Wakaya ...	...	...	...	...	...	"
Nairai ...	...	...	...	...	...	"
Gau (2 colonies) ...	...	...	...	...	...	"
Moala (4 colonies) ...	...	...	...	...	...	Aug. 1927
Vanualevu (18 colonies) ...	...	...	...	...	...	Sept. and Oct. 1927
Moturiki (2 colonies) ...	...	...	...	...	...	Nov. 1927
Ovalau (4 colonies) ...	...	...	...	...	...	"
Viti Levu (3 colonies) ...	...	...	...	...	...	Dec. 1927

Several recoveries of this insect were made a few months after it had been liberated, but the scarcity of scale from the end of 1928, which was due to the predators imported from Trinidad, made it most unlikely that more recoveries would be made. The most convincing proof of the establishment of the *Scymnus* in Fiji was obtained at Davutu and Muanicula, on the Wainunu River, Vanua Levu, where beetles were found in August 1928—nearly a year after the original liberations were made in those localities. The recoveries were, however, made on the actual trees on which the species was originally liberated and on a few trees near by, but none were made on any other trees, despite a careful search. The results were, in fact, disappointing, and contrast strikingly with those subsequently obtained with *C. nodiceps*. There was no indication of the amount of scale having been appreciably reduced by *Scymnus*, and it was quite clear that the powers of the beetle for spreading, multiplying and devouring scale were not sufficient to be of primary economic value.

VIII. IMPORTATION OF NATURAL ENEMIES FROM TRINIDAD.

By the end of 1927 it was evident that the parasites and predators imported from Java would never be able to check severe outbreaks of *Aspidiotus destructor* in Fiji. It was even doubtful whether the parasites would become established at all, and in the case of the Coccinellid there was no possibility of severe scale outbreaks being controlled, although, in the course of years, an appreciable check might conceivably have been exercised. In fact, the attempts made with natural enemies from Java definitely failed, except in so far as they indicated the kind of natural enemy which could be expected to give more satisfactory results. Parasites seemed out of the question, and if a predator was to be successful it was necessary for it to be more voracious and to have a much greater capacity for spreading and multiplication than the *Scymnus*.

At the instigation of Dr. J. D. Tothill, then Director of Agriculture in Fiji, the writer proceeded to Trinidad to investigate several species of COCCINELLIDÆ which had been recorded by Ulrich as being important factors in the control of *Aspidiotus destructor* there. The five species already described were found plentifully in Trinidad, and it was decided to ship all of them to Fiji, as it was impossible to determine in Trinidad which of them would be most likely to flourish in Fiji. All of them obviously had greater powers of spreading and multiplication than the Java species of *Scymnus*, and were also much larger.

Work was commenced in Trinidad on 25th September 1927, and after a brief survey of the habits of the Coccinellids had been made, definite preparations for shipping them were commenced. The insects were shipped on 28th January and arrived at Colon, Panama, on 1st February where they were transhipped to a steamer sailing via the Panama Canal and Tahiti, and reached Suva, Fiji, on 6th March. The voyage was therefore a long one, covering just over five weeks altogether.

1. Methods of Shipment.

It was found in Trinidad that the beetles bred extremely well in large cages, and it was decided to use this method for shipment. Nine cages of this type were constructed, and in addition three rather larger cages with double doors were used. This latter type of cage is most useful on board ship. The double doors enclose an absolutely dark compartment, so that it is possible to go into the cage without any of the contained insects attempting to escape, as they often do from cages with single doors which permit a bright light to enter. The dark compartment also greatly facilitates the introduction of new palms into the cages (a procedure which necessitates having one door wide open) without risking the escape of the insects. Each cage holds six young palms planted in kerosene tins. The size and cost of the cages with double doors are their only disadvantages. Large cages of this sort used for shipment must be built very strongly to stand the rough handling which they receive during transport. The floors must be supported by cross struts to bear the weight of the large quantity of soil in the kerosene tins and of the man who goes into the cages to attend to the contents. The cages must also be provided with long, removable wooden handles which slip through slots on either side. The size of one of these cages and its weight when fully loaded are such that four men are required to lift it, but the handles make this a simple matter and also serve to facilitate hoisting the cages on to the ship without damage.

On account of the length of the voyage it was necessary to ship a large quantity of scale with which to feed the beetles and their larvae en route. Altogether 150 young palms, growing in kerosene tins, were shipped, and all of them were heavily infested with scale previously. The 12 cages held about 70 of the palms. The other 80 were shipped in large wooden racks each of which held six kerosene tins. A number of cloth bags (3 ft. by 1 ft.) were made to cover the palms in the racks and so prevent damage from rough handling and from salt water.

The difficulties experienced in Fiji in infesting young palms with scale did not arise in Trinidad. The scale spread to the new palms extremely well and males were in the minority in most batches. The procedure was very simple. Coconut leaves heavily attacked with scale were cut off in the field, and all those leaflets which bore plenty of eggs of the scale were cut into strips measuring about 6 in. by 1 in., four of which were pinned to the underside of every unsplit leaf of the young palms. No further attention was required. The first generation of scales was not sufficient to cover the leaves, but a month later these scales were full-grown and laid eggs, and their progeny, when full-grown after another month, entirely covered the leaves. Thus, two months after the strips were pinned on, the palms were ready for use in the cages.

Half of the palms required for shipment were infested two months before the ship was due to sail, and the others one month before that date. This ensured a constant supply of large scales throughout the voyage and also eliminated the risk of most of the leaves dying before reaching Fiji as a result of the heavy infestation of scale, for it was found that leaves nearly covered with scale die before another generation of scale is hatched.

The chief precaution which had to be taken in Trinidad was the elimination of the Chalcid parasites which destroy enormous numbers of larvae and pupae of all of the Coccinellids which it was proposed to ship. The parasites were found abundantly at Cedros, where a severe outbreak of scale was in progress, and the Coccinellids became excessively abundant, but they were never found in localities where the scale was present in non-outbreak form and the Coccinellids were not abundant. The most important parasite is *Tripolycystus cryptognathus*, Girault, which attacks *Cryptognatha*, *Azya* and *Pentilia*. It is an internal pupal parasite, and will not attack larvae or prepupae. It breeds rapidly, the whole life-cycle, from oviposition to emergence, covering only 15 days. Another parasite (not named) attacks young larvae and kills them before they are full-grown.

The elimination of the parasites proved a simple matter, and none appeared in the cages at any time. This was due mainly to the rarity of the scale, and consequently of the Coccinellids and the parasites, in the vicinity of St. Augustine, where the shipment was prepared, so that the parasites never found the large assembly of Coccinellids which was made for the shipment, although many of the palms on which the beetles were breeding were kept in the open.

Two days before the ship was due to sail, about 200 adult Coccinellids, all of the same species, were put in each cage except the three with double doors. The species were segregated so far as possible in the cages. The palms in each cage already bore many larvae and pupae of the same species as the adults put in. The three large cages contained no adults at the time when they were shipped, but were filled with coconut leaves which were cut in the field two days previously and were thrust among the palms in these cages. The leaves were heavily infested with mature scale and bore large numbers of Coccinellid larvae, mostly *Cryptognatha nodiceps*. All the Coccinellid larvae and pupae were inspected for parasites before the leaves were put into the cages and all those parasitised were destroyed. A similar inspection was made daily on the ship, but no parasites appeared. The scale on the cut leaves, being mostly in the form of egg-laying female scales, lasted long enough to permit most of the larvae to pupate and consequently a large emergence of adult Coccinellids occurred during the second week of the voyage. These found themselves, on emerging, amongst the palms in the cages, and they soon began ovipositing in the scale on the leaves, the cut leaves being dead by that time. The contents of the three large cages therefore served to supplement the others in case of mishap, and to conserve the scale supply, since the scale on the palms in these cages was not attacked until the second week of the voyage.

Actually, despite the large number of scale-infested palms shipped, the Coccinellids multiplied to such an extent on the voyage that the scale supply was threatened with extinction before the ship reached Tahiti. To guard against this, it was necessary to destroy large numbers of larvae and adults. The spare palms which were shipped in the racks were put into the cages from time to time to replenish the scale supply; and the leaves from the palms already in the cages were cut off and left inside, the tins of soil in which they had been growing being thrown overboard. When the ship berthed at Tahiti with 13 days to go before she was due in Fiji, only 12 unused palms were left. It was hoped that a good supply of scale could be found in Tahiti to replenish the stock on board, but the scale proved to be very scarce on the island at the time, and no appreciable amount could be obtained. The ship stayed five days

at Tahiti, and at the end of that time it was necessary to put the last 12 palms in the cages. Even then the insects were on short rations, but fortunately this was not serious at so late a stage in the voyage, and there was no need to land a very large number in Fiji. The larvae solved the situation for themselves by becoming cannibalistic. They ate one another and ate as many pupae as they could find, but as far as possible the pupae were removed from the cages as soon as they were formed and kept separately. The larvae almost halved their number by cannibalism, but this habit enabled the fittest to mature. Special attention was paid at this time to *C. nodiceps*, which promised the best results, and the four other species suffered more in consequence, but finally all five species were landed in Fiji in ample numbers for breeding purposes. Apart from the difficulties which arose from food shortage, all the species, with the exception of *P. insidiosa*, bred most satisfactorily on the ship. The reason for the comparative failure of *P. insidiosa* was never discovered, and was particularly mysterious since it bred well in the cages in Trinidad.

The actual numbers landed in Fiji, on 6th March 1928, were :—*Cryptognatha nodiceps* 1,517, *C. similima* 98, *Azya trinitatis* 192, *Pentilia insidiosa* 22, and *Scymnus aeneipennis* 434. These figures include all stages, but the majority were adults.

2. Bulk Breeding in Fiji.

As was the case with the natural enemies shipped from Java, many difficulties arose as soon as attempts were made to breed the Trinidad Coccinellids in Fiji. In the first place, there was very little scale near Suva at the time, and the whole shipment had to be taken, within a week of landing, to Levuka, on the island of Ovalau. Levuka made a much better centre for all the scale-infested islands, and a good deal of scale was available there on coconuts, mangos, bananas, baringtonias, and other trees. Headquarters were maintained in Levuka for a year from March 1928, and all the bulk breeding was done there. The method employed at first for breeding the beetles was the same as in Trinidad and on the ship, but great havoc was wrought at the outset by ants, although no such trouble had arisen in Trinidad. Ants entered the cages and carried off larvae, pupae, and adults, but particularly pupae, of all species. The stock of *S. aeneipennis* was reduced from 220 to 29 in one night, and *A. trinitatis* suffered almost as severely. The difficulty was partly overcome by standing the cages on wooden blocks covered with "tanglefoot." Another great difficulty was the maintenance of a sufficient supply of scale. Large numbers of young palms with scale already on them were found near Levuka, and more on the neighbouring island of Wakaya, but these sources were soon exhausted. The attempts to cultivate scale on young palms were a little more successful than those made for the Java parasites, but the heavy infestation so easily and systematically obtained in Trinidad was never equalled in Fiji. This was due, as before, to a heavy predominance of male scales in many batches, and to the sudden dying off of immature scales. Cold weather was a third difficulty. The cool season begins in Fiji in April and is much cooler than in Trinidad, and although the two species of *Cryptognatha* were almost unaffected by it, except that their rate of development became slightly slower, *Azya* and *Pentilia* became unusually lethargic and refused to oviposit to a great extent, while most of their larvae died young.

On account of these and other difficulties, it was decided that some other method of bulk breeding must be devised. Breeding in glass tubes was therefore tried, and was satisfactory up to a point; it was, however, so laborious a method that it could only serve to maintain the numbers of the various species. *Azya trinitatis* will not lay at all in glass tubes, but all the other species, including even *Pentilia*, in hot weather, oviposit extremely readily when provided with plenty of scale in the tubes.

The method finally evolved, which was eventually very successful, was the simplest of all. It consisted in using large, white cloth bags instead of breeding cages and putting the bags on scale-infested banana leaves. Each bag was 5 ft. long by 1 ft. in diameter, and fitted comfortably over a large banana leaf. One end was tied round the stalk of the leaf, care being taken that there was no gap through which the beetles could escape, and the stalk was ringed with tanglefoot just below the bag to prevent the entry of ants. Any other leaves touching the bag were cut off for the same reason. A given number (decided by experiment) of beetles was put in the bag and the free end was then tied up tightly. The beetles and their progeny then fed and oviposited in the bag.

A very suitable patch of large banana plants heavily infested with scale was found at Cawaci, near Levuka. These plants provided a continuous and ample supply of scale, without attention, from May 1928 to the end of the year, and many thousands of beetles were bred on them and were distributed throughout the Colony. The heaviest infestation of scale occurs on the older leaves, and it was these that were used for the bags. While the old leaves were in use the younger ones became more and more covered with scale until, by the time more scale was needed for further generations of the beetles, the younger leaves were ready. *Aspidiotus destructor* on banana leaves is particularly large, soft and healthy, and forms an almost complete incrustation over the whole of the lower surface of each leaf. When the breeding of the beetles was at its height 43 bags were in use at the same time.

The only details of this method which required a certain amount of experiment before it could be regarded as perfected were the number of beetles initially put into each bag, and the time during which they were left in the bag. It is obvious that to get quick and uniform results the beetles used must have paired and be ready to oviposit when put in. This was ensured by using beetles which had been in another bag or a cage for at least a week. The number of beetles used was of the first importance. If too few were used much of the scale was wasted. If too many were used their progeny were so numerous that they devoured all the scale on the leaf before they were full-grown, and then began to attack one another. The time during which the original beetles were left in each bag was of importance for the same reason. The longer they were left, the more eggs they laid, and the more larvae resulted. The ideal conditions were therefore such that when the last larva in each brood was full-grown there was just enough scale left to prevent it becoming cannibalistic. In practice, it was found that a slight amount of cannibalism occurred in any case, but it was possible to reduce this to a negligible minimum. The details necessarily varied with each species, according to the rates of oviposition and development and the voracity of the larvae, but it will suffice to outline the perfected method for *Cryptognatha nodiceps*, which was the only species which proved of primary economic importance.

A large banana leaf, almost entirely covered with scale underneath, was selected, and the bag was put on as already described. Then, 20 adult beetles, about a week old, were put in: on the average this meant 10 males and 10 females, but it was found unnecessary to check the sexes. These were left in the bag for 7 days, and were then removed, having been ovipositing for a week in the bag. The bag was then left untouched for a fortnight and by this time all the larvae in the bag had usually pupated. The bag was removed and put on a new leaf with plenty of scale and all the pupae from the old leaf were put in it, so that when the adults emerged they had a good supply of scale to eat. Ten days later all the adults would usually have emerged and the majority would have already paired. The adults were therefore ready for liberation 31 days after the commencement of operations.

It was found that the number of adults produced in this way in each bag averaged approximately 300. Actually the number varied from 260 to 380, but, as a rule,

when the number of larvae exceeded about 350 the scale supply was insufficient and very heavy cannibalism resulted.

The method worked with almost mathematical precision. 20 adults of *C. nodiceps* were put into a bag on 1st July, for example, and were removed on 8th July; on 1st August, 300 adults were taken out of the bag for liberation. There were two great advantages of the method. Firstly, it required comparatively little attention, and secondly, it enabled one to have colonies of the beetle ready for liberation on a given date which coincided with the times when boats were due to be available for distribution purposes. The work of distribution in Fiji necessarily involves sea trips, sometimes of considerable length, and it is often necessary to book boats some time ahead.

By September 1928, it seemed that *C. nodiceps* was going to be completely successful, and it was certain that none of the other species was nearly so useful. Therefore, no further attention was paid to the other species after this time, and the small stock of them that then remained was liberated. *C. simillima* bred as successfully in the bags as *C. nodiceps*, except that its rate of multiplication was slower on account of its longer life-cycle. *Scymnus aeneipennis* also bred satisfactorily in the bags. *Azya trinitatis* bred in them better than in cages, but was not successful and never did more than maintain its numbers. By the end of March the stock of *Azya* was reduced to 46 adults owing to the ravages of ants, the failure of the adults to oviposit in the cages, and death of young larvae. In April the adults died off rapidly, without ovipositing much, and at the end of the month only 22 remained. These were put in a bag on a banana leaf, where they oviposited better, but the total number of individuals (of all stages) present at any one time never exceeded 30. On 19th July the adults (20) were all found to be dead in their bag, having been killed by a large *Attid* spider which had evidently been accidentally enclosed with them, and that was the end of *Azya*, as no larvae appeared in the bag. *Pentilia insidiosa* was a complete failure from the first, being apparently quite unable to cope with Fijian conditions. It oviposited very rarely, but was nevertheless maintained in small numbers (never more than 12) till July, when the last adults died without issue.

3. Liberation of Colonies of *Cryptognatha nodiceps*.

The number of beetles liberated in each locality varied greatly, but it was eventually found that 100 were ample. For distribution purposes, the beetles were packed in glass tubes (4in. by 1in.), 10 beetles in a tube. The process of moving the beetles from the bags into the tubes was rendered very simple by the fact that they feign death and drop off when touched. A tube was held in one hand, and a camel-hair brush in the other, both being inserted into the bag without removing it from the leaf. The tube was held under a beetle, which was then touched with the brush. The beetle immediately dropped into the tube. This was repeated until the tube contained 10 beetles, when it was plugged with cotton-wool and passed out of the bag to an assistant who put in a strip of coconut leaf (measuring about 3in. by 1in.) well covered with scale. In this way the 300 beetles in a bag could be transferred to tubes in about half an hour. The scale in each tube was sufficient to feed the 10 beetles for about two days, and if it was necessary to keep them longer, as was often the case when they were being taken to the more distant islands, the scale was renewed, if more was available, after two days; if no more was available, the original supply was conserved by keeping the tubes in the dark, in which circumstances the beetles remain still and eat very little.

Liberations of *C. nodiceps* were made on all the islands where scale occurred, and on the larger islands several colonies were put out in different places. The

beetles were simply tapped out of the tubes under small coconut palms or bananas infected with scale. They flew up to the leaves almost immediately.

Liberation of Colonies of Cryptognatha nodiceps in Fiji.

Island and locality					Date (1928)	No. of beetles in Colony.
1.	Wakaya :	Koro Levu	...	...	10th March	500
2.	Gau :	Garani	...	...	2nd April	400
3.	"	Vanuasou	...	...	18th July	180
4.	Ovalau :	Bureta	...	...	28th May	150
5.	"	Lovoni	...	...	30th May	150
6.	"	Cawaci	...	...	15th July	50
7.	Moturiki	...	...	...	1st June	180
8.	"	...	...	...	6th Sept.	200
9.	Koro :	Nasau	...	...	14th June	170
10.	"	Nacaga	...	...	15th June	100
11.	Nairai :	Matana	...	...	17th July	100
12.	Yanuca lailai	...	...	...	28th July	100
13.	Makagai	...	...	...	21st Dec.	100
14.	Vanua Levu :	Muanicula	...	...	21st May	400
15.	"	"	Davutu	...	21st May	100
16.	"	"	Naidi	...	22nd May	500
17.	"	"	Wairiki	...	2nd Aug.	50
18.	"	"	Wailevu	...	29th Aug.	250
19.	"	"	Dreketi	...	31st Aug.	250
20.	Viti Levu :	Nasese	...	...	24th Dec.	100
21.	"	"	Sigatoka	...	27th Dec.	100
22.	Beqa :	Nacewa	...	...	16th Oct.	220
23.	Kadavu :	Buke Levu ira	...	...	18th Oct.	230
24.	"	"	Vunisea	...	19th Oct.	100
25.	Yanuca	...	...	...	21st Oct.	100
26.	Vatu Leile	...	...	...	24th Dec.	100
27.	Waia :	Waia Levu	...	...	28th Sept.	150
28.	Naviti :	Sau Sau	...	...	28th Sept.	150
29.	"	Gunu	...	...	29th Sept.	100
30.	Moala :	Matuku	...	...	23rd Sept.	200
31.	"	Vuci-ni-masi	...	...	23rd Sept.	200
Total					...	5,680

At the end of December 1928, bulk breeding was no longer necessary and was abandoned, as *C. nodiceps* had been distributed to all the islands where scale was known to occur, and was already so abundant in some localities that it could be obtained in indefinite numbers in the field.

4. Liberation of Colonies of other Trinidad Species.

Colonies of the other species were put out as follows :—

Cryptognatha simillima.

1.	Naigani	...	...	31st May	250
2.	Moturiki	...	...	1st June	100
3.	Gau (Vanuasou)	...	...	18th July	100
4.	Ovalau (Cawaci)	...	...	5th Aug.	100
5.	Vanua Levu (Naidi)	...	...	29th Aug.	400
6.	Ovalau (Cawaci)	2nd Oct.	50

1,000

Azya trinitatis.

1. Ovalau (Cawaci)	16th May	25
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Pentilia insidiosa.

None were liberated.

Scymnus aeneipennis.

1. Wakaya (Koro Levu)	10th March	100
2. Moturiki	6th Sept.	130
3. Ovalau (Cawaci)	2nd Oct.	100

		330

5. Results of Liberation of *C. nodiceps*.

As a means of controlling *Aspidiotus destructor*, *C. nodiceps* was a remarkable and spectacular success. Only 9 months after the shipment was landed in Fiji, the scale, though by no means wiped out, was definitely brought under control in all the more important islands of the Group; and after a further 9 months (that is by September 1929) the scale was not only controlled on every single island but was so rare in many localities in which it formerly abounded that living batches of it could only be found with difficulty. Such rapid and thorough results as these exceeded all expectations.

From 1928 to the time of writing (July 1934) not a single new outbreak of scale has occurred in any of the islands where outbreaks were always present previously. The beetles, therefore, not only reduced the occurrence of scale to negligible proportions, but also are maintaining what appears to be a permanent and very effective check on it. Moreover, the nature of the host-plant of the scale proved, in nearly all cases, quite immaterial; mangos, bananas, barringtonia, and other trees and plants, being freed from scale as rapidly and thoroughly as coconuts.

A few instances will suffice to illustrate the activities of *C. nodiceps* on a large scale. On the west side of Savu-savu Bay, Vanua Levu, there is a long, continuous coastal belt of tall coconut palms extending inland in some places for half a mile. The palms are, for the most part, much too close together, and in many places they are interspersed with other trees and have a very dense and bushy undergrowth. These are conditions in which scale thrives, and in 1927 and 1928 a very severe outbreak occurred, extending for about 3 miles along this coast with very few gaps. Every coconut tree within this belt was affected, and except for those trees along the beach, which were less seriously attacked, nearly all of them were yellow and sickly-looking, the only green leaves being the youngest at the top of each tree. In 1928 the scale was still spreading, both inland and at each end of the infested area.

On 29th August 1928, 250 adults of *C. nodiceps* were liberated near the native town of Wailevu, approximately in the centre of the scale area. In December 1928, the beetles had spread for about half a mile on either side of the original point of liberation, being abundant along about a mile of coast. Not only had they spread for this distance, but they had attacked, and were still attacking, the scale on every single tree. As they spread they appeared to hunt out every patch of scale in their vicinity before moving on. In the centre of the area through which they had already spread, their larvae were so abundant that they could be seen from the ground on tall trees as white patches on the undersides of the leaves, and the pupae formed smaller but even more conspicuous white patches on the leaf-stems and at the tops of the trunks. Adults swarmed on every tree, and in the heat of the day they could be seen from the ground flying around the leaves.

In March 1929, the position was quite different. The beetles were abundant in all stages at each end of the scale belt, but in the centre of it, where they were originally liberated, they were now rare, and scarcely any living scale was to be found for a distance of about half a mile. Moreover, the young leaves were not becoming infested with scale when they opened.

This coast was not visited again until June 1930. By this time all the scale had entirely and literally vanished, and *C. nodiceps* had vanished too. Not a single larva, pupa, or adult of the beetle, could be found at any point of the belt. The appearance of the trees was completely changed also, the yellow colour having given place to green. Most of the old leaves which were so heavily infested a year previously had either dropped off or were still hanging down the trunks, but a few of the yellow leaves still remained. These, however, had no living scale on them, and the great majority of leaves on all the trees were green and healthy, and all were entirely free from living scale. In short, the trees were obviously recovering, and there was no indication of the scale breaking out again. Thus the very severe outbreak of scale on this coast was entirely wiped out in about 18 months.

A remarkable example of the thoroughness of *C. nodiceps*, as well as its rapid spreading, was afforded on the south coast of Vanua Levu, east of Savu-savu Bay, along the road from Naseva to Nagigi. All along this road, a distance of about 12 miles, there were many bad outbreaks of scale for several years up to 1928, when *C. nodiceps* was liberated there. This coast is very irregular and hilly, and the patches of coconut palms are separated by big areas of forest and by densely wooded promontories. In many places the coconuts grow so thickly that they form a continuous roof overhead, and it is in these areas that the scale outbreaks were most severe. On 22nd May 1928, 500 *C. nodiceps* were liberated at Naidi, near the half-way point of the road to Nagigi. On 19th March 1929, beetles were abundant all along the road as far as Nagigi, having spread entirely of their own accord for about 6 miles in both directions. This involved crossing areas of forest in which there were no coconuts and very little scale. There was not a single patch of scale in the 12 miles of coast which had not been discovered by the beetles. In some places there had been no outbreaks for some time, and the scale was only present in one or two small batches on a few leaflets here and there, but even these had been visited by *C. nodiceps*. The coconut estate of Devadara was almost entirely free from scale at the time, but a very small batch was found in 1929 on one leaf of a small palm in the middle of the estate. No other scale could be found near by and there were no outbreaks within half a mile in any direction. Yet two beetles were found feeding on this one small colony of scale. In June 1930, when this coast was again visited, the scale had completely gone everywhere and the beetles were very rare. The only beetles found were feeding upon another species of scale, *Diaspis pentagona*, on the trunk and branches of a mulberry tree at Devadara. The coconuts everywhere were entirely devoid of scale and beetles.

It is unnecessary to give more examples, as precisely the same results were obtained on every island. Small outbreaks were cleared up in 6 months, and the largest within 2 years. The scale vanished not only from coconuts but also from bananas, and every other tree or plant which it formerly attacked.

The extreme scarcity of both *Aspidiotus destructor* and *C. nodiceps* in 1930 led to the suspicion that the latter might die out on some islands, especially as it appears to confine itself to the few soft Diaspine scales, none of which, apart from *A. destructor*, has ever been plentiful in Fiji. But the discovery in 1930 of a number of beetles and larvae feeding on *Diaspis pentagona* at Devadara, long after all the *Aspidiotus destructor* had disappeared along that coast, shows that *C. nodiceps* is able to maintain itself. The lack of any new outbreaks since 1928 further testifies to its continued presence on all the islands where it was liberated. It is scarcely necessary to point out that there is no possibility of *C. nodiceps* causing *A. destructor* to become extinct

anywhere, but it is now clear that the equilibrium established between the beetle and the scale is such that the scale is now a rare insect in Fiji, and no longer of economic importance. It is likely that small outbreaks of scale will occasionally occur in the future, but there is every prospect of *C. nodiceps* always re-appearing to suppress them.

One of the most important results of the importation of *C. nodiceps* is that those islands which the scale has never reached are now safeguarded. The scale may reach them yet, but this possibility is now immaterial, as *C. nodiceps* could at once be introduced. The most important coconut island in Fiji is Taveuni, which enjoyed complete freedom from outbreaks of *A. destructor* until 1931, despite its close proximity to Vanualevu and the large number of boats which are constantly crossing to and fro between the two. In 1931 an outbreak was discovered at the north end of Taveuni, and this is the first record of the occurrence of *A. destructor* there. It is most probable that the scale was actually present there for two or three years at least before it was discovered, despite the sharp look-out that had been kept for it. This outbreak in Taveuni, which was studied and controlled by R. W. Paine, who introduced *C. nodiceps* from Vanualevu, was definitely useful as a further proof of the continued presence and utility of *C. nodiceps* in Fiji, even though its main food supply, *Aspidiotus destructor*, had been reduced to negligible proportions in all its former haunts some years previously. An account of the Taveuni outbreak, by R. W. Paine, follows.

6. The Scale Outbreak on Taveuni in 1931 (by R. W. Paine).

Amongst certain coconut planters on the island of Taveuni there exists the conviction that in 1909 there was a scale outbreak on an estate near the southern end of that island. "Kavika" trees are supposed to have been badly attacked, and the pest to have spread from these to coconuts. The owner of the estate is said to have cut down all the infested trees, eradicated the pest, and "hushed up" the whole matter.

If this story represents the true facts it might account for the early capture of the parasite *Aphelinus chrysomphali* on Taveuni, as evinced by the discovery of the specimen mounted by Knowles, referred to on page 15. It would, however, seem unlikely that an estate owner, however anxious he may have been to avoid publicity, would refrain from sending some samples of his diseased crop to the Department of Agriculture before employing any such drastic measures as must have been necessary for the eradication of this pest.

Although of sufficient interest to mention here in an account of the history of scale on Taveuni we can find no published record of this supposed outbreak, and it was generally considered, both in official circles and, we think, amongst the majority of planters on the island, that *A. destructor* was never present on Taveuni before the commencement of the outbreak which was first reported in 1931.

The apparently remarkable freedom from scale enjoyed by Taveuni during the years just prior to the introduction of *C. nodiceps* led to a thorough inspection of the most favoured host-plants on this island during 1927, but no scale was found. Another search was made towards the end of 1928: again without the discovery of the pest.²³

In June 1931 *Aspidiotus destructor* was found by Simmonds on seedling nuts at Mua estate; and on further investigation it was found that small outbreaks of this pest had begun at several places in the north end of the island. Scale was, in fact, in sufficient abundance on Taveuni at that time to indicate that its arrival on the island must have taken place at least six months previously. But, as the pest was almost certainly introduced either from Koro or Vanualevu, on which islands it had by the end of 1930 been reduced to negligible quantities by the depredations

of *C. nodiceps*, it seems probable that it reached Taveuni in 1929, but did not become sufficiently abundant to be noticed until two years afterwards.

Thus it would appear to us that in the year 1929 lies the date on which scale arrived at Taveuni, because it is difficult to see how it could have reached this island after it had been so considerably reduced on neighbouring islands; and yet there is no doubt whatever that the recent scale outbreak on Taveuni owed its origin to newly introduced individuals and not to survivals from some early outbreak.

In July 1931, Paine collected 200 adults of *C. nodiceps* for transportation to Taveuni from a mulberry tree at Devadara (Vanualevu). The beetles were feeding, rather reluctantly it seemed, on the scale, *Diaspis pentagona*, which, however, was rapidly killing its host. It was singularly fortunate that *C. nodiceps* was so readily procurable at that time, since the apparently complete absence of *A. destructor* along the Vanualevu coast made it appear likely that a prolonged search would be necessary for the Coccinellids. Moreover it is very satisfactory to know that *C. nodiceps* has other hosts in Fiji and can survive in places where *Aspidiotus* is apparently non-existent.

The colony of Coccinellids collected from Devadara was liberated partly at Mua, in the Malay coconuts, and partly at Nabokoyia, in the planting of "niu leka" (a native, dwari coconut). They oviposited in both places and larvae were found a few weeks later. At this time scale was spreading rapidly from about six centres in the Mua and Nabeka estates, and a small but severe outbreak had started at Nacaugai estate, distant about two miles from Mua across the north end of the island.

Thirteen beetles—all that could then be recovered in the colony site at Nabokoyia—were transported to Nacaugai at the end of July. In this latter locality scale had spread to only one high coconut tree, but was really bad on almost all the young coconuts and bananas growing in the paddock below. The area of this outbreak was not much more than half an acre in extent, but there was enough scale present to insure the rapid spread of the pest during the succeeding few months had not *C. nodiceps* been liberated there.

Thousands of the beetles were visible at this site during the months of September and October, and by January of the following year (1932) the scale had all been destroyed. The beetles, moreover, had spread to other scale-infested trees more than a mile distant.

The capabilities of *C. nodiceps* as a controlling agent of *A. destructor* are well demonstrated by the history of this small outbreak of that pest at Nacaugai. The offspring of only thirteen adult beetles checked the advance of, and in six months completely eradicated, a scale outbreak comprising originally about half an acre of heavily attacked bananas and young coconuts.

Although of no effect so far as the course of the small outbreak at Nacaugai is concerned it is necessary to add here that the prompt destruction of kavika trees over much of the neighbouring land on Nagasau estate was in all probability an important measure of control and responsible for the freedom from scale of Nagasau estate at the time when Mua was badly attacked.

At the end of 1931 scale was still spreading rapidly from the half dozen or more foci located over the Mua estate as a whole.* In these areas, in addition to coconuts, kavika trees were badly attacked, and scale had even spread to guava and "ka moce" growing beneath the coconuts. In February 1932, a variety of the Coccinellid, *Chilocorus nigritus*, F., appeared suddenly and was fairly abundant in this locality; more especially on the kavika trees, where adults and larvae of this beetle were destroying much scale.

* Including the southerly extensions of it—Nabeka and Nabokoyia.

In April, the manager of the estate reported that at last *C. nodiceps* had become abundant at Nabeka, but that scale was still spreading. In August, a further report stated that after several colonies of the predator had been distributed in each badly infested area the scale had been materially reduced at the centres from which it had originally spread; but also that several fresh outbreaks had started, and that it would probably be more than six months before scale had been cleaned up over the whole estate. The *Chilocorus* was reported to have disappeared, its departure being as sudden and inexplicable as its appearance.

In addition to the outbreaks of scale at Mua there was a severe infestation extending over several acres along a gully on the neighbouring estate to the southward (Mt. Vernon). The predators were released in this locality at the end of 1931.

Almost all the scale outbreaks in the north-west part of the island were located along valleys, demonstrating very strikingly the direct or indirect controlling effect of winds in the high grounds. It was also evident that kavika trees in many cases provided the foci from which scale had spread to coconut. This was not due to the fact that *A. destructor* prefers kavika to coconut as a host-plant, but to the fact that the scale was spread from place to place by some animal which visits kavika and not coconut.*

South of Mt. Vernon estate traces of scale were found in seedling coconuts as far as Waiyevo—half-way along the island, and ten miles distant from Mua—but no outbreaks had been reported from the south by the end of 1931. At Qacavulu estate, in the southern half of the island, a transparent scale was found on the leaves of papaya and avocado. Some of these scale-infested leaves were pinned on coconut leaves, but the scale did not migrate to the coconut. Subsequently, the scale from both plants found at Qacavulu was determined at the British Museum as *A. destructor*, var. *transparens*, i.e., the same insect which was at that time causing the scale outbreaks in the north of the island.

The pest was not brought under control in the north of the island quickly enough to prevent its spread to the south, which in the absence of any quarantine measures was almost certainly brought about by the transference of scale-infested coconut leaves in the form of baskets. An outbreak was reported at Vuna in July 1932; but colonies of the beetle predator were quickly liberated there and control was effected before the scale had spread over any considerable area. Other small outbreaks in the south of the island were in like manner quickly brought under control, and it is noteworthy that scale was destroyed in the south at least three months before it was finally controlled at Mua.

It was not until the early part of 1933 that scale was sufficiently reduced at Mua to enable the coconut trees in the affected areas to begin to recover healthy foliage. At the end of that year Paine inspected the former scale areas over Mua estate and noted an almost complete recovery of the coconuts, which were in nearly all cases entirely free from scale. But the pest was still much in evidence on kavika trees, where *C. nodiceps* was found in small numbers. The reason for scale lingering for so long on kavika is probably that scale-attacked leaves from these trees are quickly shed, so that a large number of immature beetles perish by falling from their food-plant, and their host travels spasmodically from tree to tree instead of remaining on the same tree for several months as it does on a coconut palm.

Practically two and a half years elapsed from the time when *C. nodiceps* was introduced to Taveuni until the final eradication of scale from the coconut trees. This contrasts with the rapid control of scale brought about in other parts of the Group. Undoubtedly the presence of large numbers of kavika trees amongst the

* Mr. H. Stuart-Forbes, manager of Vunilagi estate (Vanualevu) and a keen observer, told us that he attributes the escape of his estate from scale attack to the great scarcity of kavika trees, from which he asserts that scale is spread by fruit bats (*Pteropus* sp.).

coconuts, providing an abundant supply of alternative hosts for the scale, on which the beetle, for reasons already stated, is unable completely to eradicate its host, has been the main factor in prolonging the outbreak.

The history of this scale outbreak on Taveuni is particularly interesting as it has been under observation from start to finish and provides additional convincing proof of the remarkable powers of *C. nodiceps* in the control of this serious pest. Judging by the rapidity with which *Aspidiotus* was spreading at Mua, Nabeka, and Mt. Vernon during the latter part of 1931, it is not too much to say that *C. nodiceps* was directly responsible for saving Taveuni from what would, by the end of 1932, have developed into the most widespread and severe devastation of coconuts the island had ever experienced.

7. Results of Liberation of other Trinidad Species.

Of the three other Trinidad species liberated in Fiji, *Azya trinitatis* is probably the only one which did not become established. No trace of its larvae, pupae, or adults, was ever found at Cawaci after the 25 adults had been liberated there.

Scymnus aeneipennis certainly became established temporarily, and possibly permanently, in Fiji, but it is possible that the rapid suppression of the scale by *C. nodiceps* occurred before *S. aeneipennis* was sufficiently established to maintain itself permanently. Many adults and larvae were seen at Cawaci in November 1928, a month after the original liberations were made there. None were then seen till January 1929, when two adults were found on coconuts in the same locality, but the scale was then very rare. No recoveries have since been made there or elsewhere, but as no opportunities of making a careful search have arisen, it is impossible to state whether the species became established permanently. In any case, there was every indication that this species, by itself, would have been unable to cope with the scale in Fiji. It was not sufficiently voracious, and its rate of multiplication was too slow.

Cryptognatha simillima became well established in 1928 and 1929 in four of the five localities in which it was liberated, the only island on which no trace of it could be found subsequently being Moturiki. At Cawaci, it became plentiful and remained so until the scale became scarce. At Vanuasou on the island of Gau, and at Naidi on Vanualevu, it was recovered 4 months, in each case, after it was originally liberated, but in both places it was rare as compared with *C. nodiceps*. The only real test of the capabilities of *C. simillima* was made on Naigani (near Ovalau), where it was the only species liberated. It became plentiful on this island, but its rate of multiplication was much slower than that of *C. nodiceps*. Many adults were found, on 26th September 1928 (4 months after the species was liberated there), on a scale-infested palm about 100 yards from the tree on which the original adults were placed. The scale on the latter tree had been completely cleared up, and the old larval and pupal skins of *C. simillima* were common on the leaves. The scale was not very plentiful on the island at the time, but odd trees here and there, in different parts of the island, were severely attacked. A year later, the scale had entirely disappeared all over the island, and the beetle with it, and no outbreaks have occurred since. Naigani is a small island and may not be large enough to support *C. simillima* permanently, but the chances are that the beetle has become permanently established there.

There was every indication, at Naigani and elsewhere, that *C. simillima* was capable, by itself, of suppressing the scale in the course of time, but it certainly would be very much slower than *C. nodiceps* and would permit the scale to do much more damage in new outbreaks before checking it. It is quite as voracious as *C. nodiceps*, but its rate of multiplication, and consequently its capacity for spreading, are very definitely inferior.

8. Reasons for the Success of *C. nodiceps*.

The complete success of the introduction of *C. nodiceps* is attributable to the following facts :—

1. It breeds continuously throughout the year.
2. It has no serious natural enemies in Fiji.
3. It is very voracious, as a larva as well as an adult, and is not a general predator.
4. Its adult life is very long.
5. Its rate of multiplication is high.
6. It has remarkable powers of dispersal.
7. It can survive even when *Aspidiotus destructor* has become exceedingly rare.

1. The seasonal changes in Fiji are not sufficient to affect the rate of multiplication or the other activities of *C. nodiceps* greatly. The life-cycle is lengthened appreciably in the cool season but not enough to reduce the rate of multiplication seriously. There is therefore no lull in its activities, and the scale has no opportunity to reassert itself.

2. In Trinidad, the effect of *C. nodiceps* on severe outbreaks of scale is considerably reduced by parasites. In Fiji it has no parasites, and no regular predatory enemies. Ants rarely attack it in any stage in the field, though they have occasionally been seen to destroy its larvae and pupae.

3. *C. nodiceps* is far more voracious, both as a larva and as an adult, than any other species introduced into Fiji from Java or Trinidad, with the exception of *C. similima*. It feeds almost continuously throughout the day, except when ovipositing, and when *Aspidiotus destructor* is plentiful it eats nothing else and does not move far until most of the scale in its immediate vicinity is destroyed.

4. The great length of the adult life has far-reaching effects. Firstly, each female oviposits continuously for a period which is greater than the complete life-cycle of its species, and therefore all stages are always present at the same time and the checking influence exerted on the scale is constant and cumulative. Secondly, every adult lives long enough to see its great grand-children, and sometimes to see still another generation. Hence, when the beetle begins breeding in a new locality the controlling influence exerted soon becomes much greater than it would if the adult life was short. Thirdly, the long adult life greatly increases the beetle's capacity for dispersal. It can travel great distances in search of new sources of scale, provided that it can find just enough food for its needs *en route*.

5. The life-cycle is unusually short for a Coccinellid, and the egg capacity, though not particularly large, is not small. The rate of multiplication is therefore high. It is, in fact, comparable to that of the scale, and since each individual of *C. nodiceps* devours many hundreds of scales in the course of its life it is capable of "overtaking" the scale rapidly in an outbreak.

6. The remarkable powers of dispersal are due to three factors. Firstly, the rapid rate of multiplication makes it necessary for the beetles to move elsewhere frequently for food. Secondly, the length of the adult life enables them to survive while travelling over long distances. And thirdly, their remarkable capacity for detecting small quantities of scale in areas which are otherwise devoid of it enables them to find food before they succeed in finding scale outbreaks of proportions large enough to induce them to remain.

7. The permanent existence of *C. nodiceps* in Fiji depends upon the ability of that insect to survive periods when its normal food, *Aspidiotus destructor*, is very scarce or absent. It is now clear that *A. destructor* itself will always survive in Fiji, though it appears to have been entirely wiped out over limited areas. A few individuals here and there escape from the beetles through being situated in narrow

niches in the trees or plants where they are inaccessible to the beetles and their larvae. Others escape for a while through being on particularly isolated trees, from which a partial reinfestation of areas in which the scale formerly was abundant, but has since been wiped out, may occur. The tardiness of the destruction of the scale on kavika trees, to which R. W. Paine has drawn attention, is also a factor causing partial reinfestation, and preventing complete extinction of the scale. These factors ensure the permanent existence of just sufficient *A. destructor* to support *C. nodiceps* in a condition of great rarity.

The fact that *C. nodiceps* has an alternative food in Fiji in the form of *Diaspis pentagona*, which is not a serious pest in Fiji, is most important in this respect. This scale cannot be destroyed to the same extent as *A. destructor* because it commonly infests the bark of trees and takes up positions in narrow crevices in the bark where it is quite inaccessible to *C. nodiceps*. When all the accessible individuals have been destroyed the beetles temporarily depart and reinfestation of the exposed parts of the trees immediately results.

For these and other similar reasons, *C. nodiceps* can be expected to survive in Fiji and therefore to be a permanent safeguard against outbreaks of *A. destructor* on all crops.

IX. COMPARATIVE VALUE OF PARASITES AND PREDATORS AS CONTROLLING FACTORS FOR *ASPIDIOTUS DESTRUCTOR*.

The campaign against *Aspidiotus destructor* in Fiji was instructive in that it showed what qualities should be looked for in a natural enemy in deciding whether it is suitable for use as a control for scale.

A parasite or predator introduced into a new country where scale is already rampant and occurring in outbreak form has two tasks before it. In the first place it must be capable of multiplying and spreading sufficiently rapidly to "overtake" the scale in the worst outbreak. And secondly, having reduced the scale to non-outbreak state, it must be able to keep it in that state. Now, any natural enemy which is capable of fulfilling the first of these tasks can be expected to fulfil the second also; but it does not follow that a natural enemy, which, when liberated in an area where scale is present in a non-outbreak condition, can keep it in that condition, will also be able to overtake and suppress severe outbreaks. Moreover, outbreaks of a passive pest like scale are often due to factors, such as climatic changes and the condition of the food, which have nothing to do with natural enemies; and therefore they are liable to occur despite the presence in the localities in question of a natural enemy which is ordinarily capable of keeping the scale in a non-outbreak condition. Outbreaks of passive pests differ in certain respects from those of active pests, and it is necessary, in selecting natural enemies for introduction into new countries, to bear in mind the special conditions which prevail in outbreaks.

Aspidiotus destructor is one of those pests whose ravages are irregular and sporadic. The damage is not done steadily and uniformly from year to year and throughout every coconut area, like that of *Tirathaba*, for instance, which is a lepidopterous pest of coconuts in Fiji. The damage is only done in the special circumstances which constitute an outbreak, and it is just these circumstances with which the parasites and the less voracious predators of the scale do not seem able to cope, although they might very well be able to cope with an insect whose ravages were constant and uniform, but less severe locally.

A scale-insect cannot move to new trees and new areas of its own accord. It must remain on one leaf, and its progeny must remain near it. The young larvae, so long as there is still green tissue in the vicinity of the parent scales, wander for a short time only before settling down, and extremely few of them can be carried by outside agencies to other trees. There comes a time, however, after several generations, when the infested leaves become absolutely covered with scale, so that

in the next generation only a very small proportion of the young larvae can find feeding space. Every leaf is covered with countless thousands of incessantly wandering larvae, nearly all unable to settle down for lack of space, and it is chiefly at this time, and not before, that the scale is spread to new trees. Every bird and bat which settles on, or knocks against, the leaf inevitably carries larvae away on it. At the same time, an enormous number of larvae die through lack of food, and it is because of this enormous natural surplus, responsible though it is for the death of countless thousands, that the outbreak of the pest spreads rapidly. Therefore, a natural enemy, if it is to control the scale, must be capable of destroying all the individuals before the surplus condition is reached, and this demands an exceptionally high rate of destruction. In other words, the natural enemy has a definite time limit, which is equal to the time required by the scale to cover a leaf. In no other way can it forestall the natural surplus.

The case of an active pest, such as a lepidopterous or coleopterous insect, is quite different. There is, as a rule, no natural surplus, because the insect is capable of spreading without outside assistance, and the spreading is more or less continuous. The natural enemy has, in this case, no time limit in which to do its work. It must be capable, sooner or later, of destroying the pest to the extent of 100 per cent., but the time it takes is relatively immaterial and is not an essential factor in the control of the pest.

An attempt to control a scale occurring, like *Aspidiotus destructor* in Fiji, in severe sporadic outbreaks, by means of parasites such as those found in Java, appears, in the light of present knowledge, to be foredoomed to failure. Each individual of the parasite, in the course of its development, can only destroy one individual of the pest, and none of the Java or the Tahiti parasites is capable of multiplying appreciably more rapidly than the pest. In these circumstances it is impossible for a parasite to overtake the scale within the prescribed time limit, and the Java parasites, as well as those from Tahiti, though theoretically capable of maintaining the scale in a non-outbreak condition, were inherently incapable of reducing it to that condition in the first place. The same applies to the predators, which were introduced from Java, and to the less voracious of those from Trinidad. Only an insect, like *C. nodiceps*, of quite exceptional voracity and with a high rate of multiplication comparable to, or exceeding, that of the scale, could possibly control outbreaks. Each individual of *C. nodiceps* can destroy hundreds of scale-insects of all stages, including eggs, in the course of its larval and adult life, and the rate of destruction of scale-insects by it is incomparably greater than that achieved by any known parasite.

The problem of the control of scales which occur in outbreaks is one of those rare instances where a predator may be successful and all parasites fail. Predators as a class are less efficient than parasites, chiefly because their rate of multiplication is usually inferior and they are not sufficiently specific in their choice of food. Most of the predatory Coccinellids which have been introduced into new countries for pest control have proved unequal to the task, but there are a few exceptions, of which *C. nodiceps* is one and the now classic case of *Nedalia cardinalis*, introduced into California to control the Fluted Scale, is another. Parasites have invariably failed as complete and permanent controls for scales, although they are definitely useful in a subsidiary capacity. The well-known case of *Scutellista*, introduced into California against the Black Scale, affords a good example. Although a parasitism of 75 per cent. is often obtained by *Scutellista*, the scale is not sufficiently checked for economic purposes.

In conclusion, therefore, it may be stated that, as a general rule, it is desirable to seek predators rather than parasites for the control of a scale which, like *A. destructor*, does its damage only by severe outbreaks; and that successful control can be established only by means of a predator which is relatively large and voracious,

whose life cycle period is not appreciably greater than that of the scale, and whose egg capacity is not appreciably less.

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THE EFFECT OF HIGH MAXIMUM TEMPERATURES UPON THE LONGEVITY OF *GLOSSINA SUBMORSITANS*,* NEWST., AND *G. TACHINOIDES*, WESTW.

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Introduction.

It is curious when one considers how much has been written upon the bionomics of tsetse-flies that very few data have been accumulated upon the seasonal variations in longevity of the adult.

When studying *Glossina morsitans* in Tanganyika Territory the writer showed that fluctuations in fly density could be correlated with variations in the evaporation and saturation deficiency readings; he suggested that these factors affected the size of the population by their direct effect on the longevity of the adult fly:—Should the combination of temperature and humidity be favourable to tsetse the adults will presumably live longer, and, providing emergence of young flies continues, an aggregation of tsetse will ensue, resulting in an increase in population; on the other hand, should the combination be unfavourable, the longevity of fly presumably decreases, the females die before they have had time to produce many offspring and a decrease in the tsetse population results (Nash 1933 a, 1933 b).

With a view to proving whether the above reasoning was justifiable, the writer decided that an experiment upon the monthly variations in longevity should play an important part in a similar ecological investigation that he has recently started at Gadau in Northern Nigeria. At least another year will be needed before enough data upon seasonal longevity and the size of the fly population can be produced, but an important side-line has already evolved from the initial experiment, namely, the effect upon tsetse longevity of the high maximum temperatures recorded in the late dry season.

Description of Longevity Experiment.

On each of the first seven days of each month fifteen freshly emerged *G. submorsitans* and fifteen *G. tachinoides* are isolated in two separate cages made of chicken wire, covered with mosquito netting; these cylindrical cages are about $4\frac{1}{2}$ inches in height, with a diameter of $3\frac{1}{2}$ inches, and in each is placed a pleated filter paper for the convenience of the occupants. The sex proportion is kept at 7 males to 8 females, giving a female percentage of 53, which is approximately the percentage obtained from puparia collected in the bush. (N.B.—It has not always been possible to obtain these exact numbers and this sex proportion of freshly emerged fly on the day required, but every effort is made to keep these figures constant.) By the seventh day of the month each species of tsetse is represented by seven cages, giving a total of 105 flies (49 males to 56 females).

Each batch of flies is given an opportunity of feeding daily; guineapigs are used for the first feed only, because their soft skins are easily penetrated by newly

* It will be noted that *G. submorsitans* is treated as though it were a species distinct from *G. morsitans*. Professor Newstead's nomenclature has been adopted purely as a matter of convenience, the name "*G. morsitans*" being used for these tsetse in East Africa and "*G. submorsitans*" being employed for the distinct race or species found in West Africa. In the writer's experience the habits of these two races or species are so different that treating them as distinct species with different names is a great convenience for purposes of reference.

hatched flies, but subsequently sheep are employed. Each morning all deaths are recorded.

At first the flies were kept in the laboratory, windows and doors being open day and night, but it was found that over a period of eleven days the mean maximum temperature of the room was 4°F. cooler than in a Stevenson screen outside, and that the mean minimum room temperature was 15°F. warmer. To obtain natural conditions, a special hut was built under the shade of a Cassia tree: it has no walls but a very heavily thatched roof which extends to within 2½ feet of the ground. Inside is a large table, 2½ feet high, upon which the tsetse cages are kept, so that the flies are protected from sun and rain but not from wind. In the immediate vicinity of the cages temperature and humidity readings are obtained from a recording thermohygrograph, which is often checked against an accurate dry and wet bulb hygrometer: the evaporative power of the air is measured by a Livingston white anemometer sphere. These readings from the table in the grass house are almost identical with those obtained from the Stevenson screen which is out in the open; hence the ventilation must be effective, and conditions should closely approximate to the natural climate experienced under a heavy shade-tree, or in a dense thicket in fairly open savannah country.

Effect of High Maximum Temperatures upon Seasonal Longevity (fig. 1).

It was not considered safe to base conclusions upon the number of survivors from the daily batches of 15 flies of each species, and so the data used in fig. 1 were divided into two groups:—Group I includes the data obtained from the three batches made up from fly that emerged on the 1st, 2nd and 3rd of each month; and Group II from emergences on the 5th, 6th and 7th: hence each group starts with 45 flies at the beginning of each experiment, the only exception being with *G. submorsitans* in January when only 35 young fly were available.

Experiments were started in the first week of the months of January, February, March and April. It will be seen that in the experiment starting in January, the cold season, both species were very long-lived, there being survivors up to two months later. In experiments starting in the subsequent months, when the daily maximum temperatures were rising, longevity rapidly decreased, until in April no flies of either species survived more than 5 days in Group I, and 10 days in Group II.

Frequently, it will be shown below that sudden reductions in the numbers of survivors occur when the maximum temperature rises above 100°F. Exact coincidence of such temperature peaks with the sudden decreases in the numbers of survivors cannot be expected, as, owing to the grouping of the duration of life into five-day periods, the effect of the death of many flies on the first day of a period would not be recorded on the graph until four days later.

1. Early February Heat Wave (4th to 7th Feb. Max. Temps.:—100°, 100·5°, 102·5° and 102·2°F.).

This hot weather tended to accelerate mortality among flies of the January experiment which were 30–37 days old by this time; however, it produced no effect upon the young *G. submorsitans* of the February experiment, though it increased the initial mortality among young *G. tachinoides*.

2. Early March Heat Wave (1st to 3rd March. Max. Temps.:—101°, 102° and 103°F.).

This spell definitely accelerated mortality among flies of the February experiment which were 24–31 days old; in the March experiment, Group I, it affected young *G. tachinoides* but not young *G. submorsitans*; it could not affect flies of Group II, as they did not emerge until afterwards.

3. The mid-March Heat Wave (14th to 17th March. Max. Temps.:—103·7°, 105°, 104·3°, 101·3°F.).

This heat wave definitely accelerated mortality among flies of the March experiment that were 8-15 days old.

4. Early April Heat Wave (1st to 4th April. Max. Temps.:—105°, 102·5°, 106·5° and 106°F.).

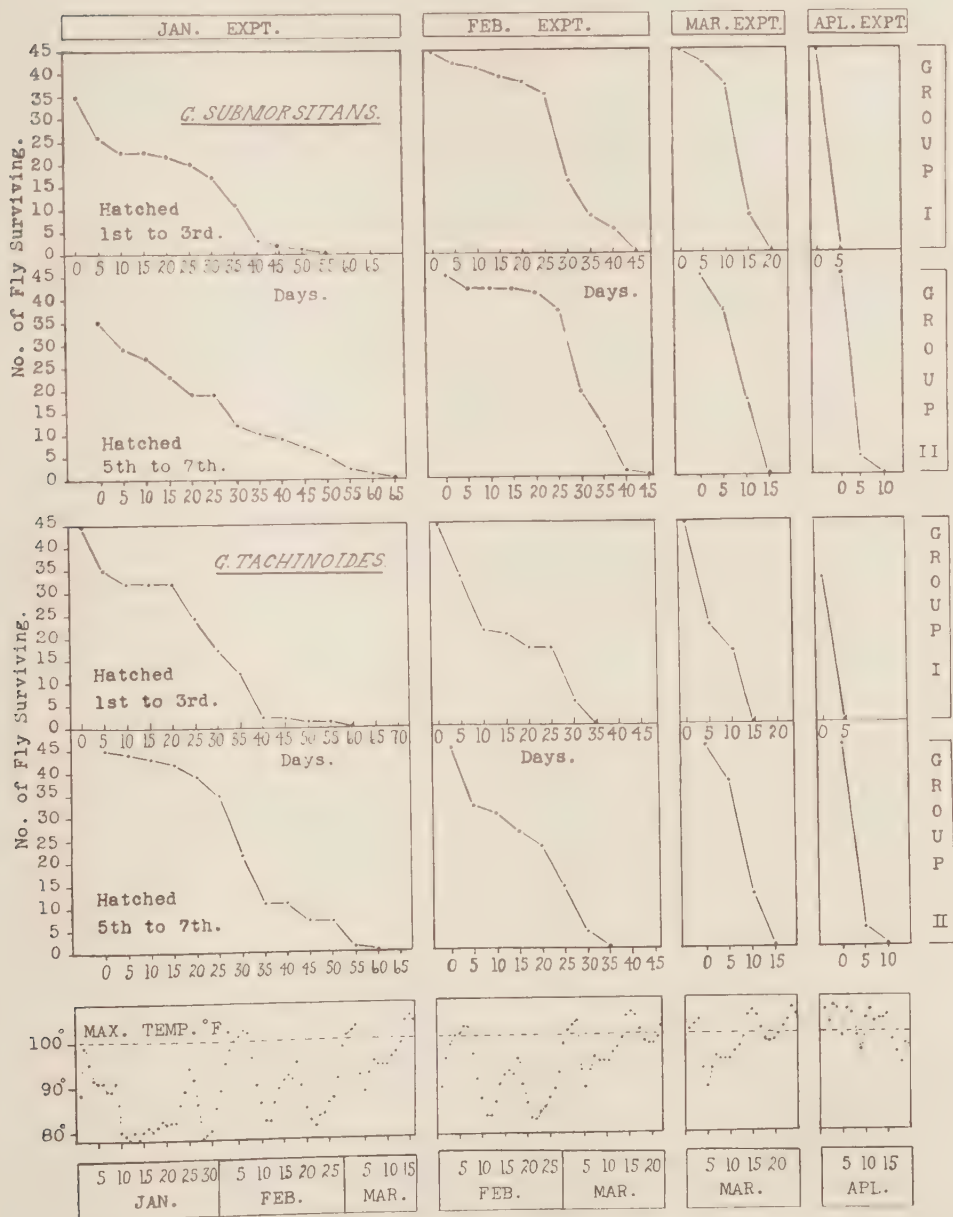


Fig. 1. The effect of high maximum temperatures upon seasonal longevity of *Glossina submorsitans* and *G. tachinoides*.

This hot spell could only affect Group I, and it resulted in the immediate death of the young tsetse of both species. Further heat waves in April will be dealt with in the next section, which deals with fig. 2.

Examination of fig. 1 has suggested that (a) maximum temperatures of 102.5° or 103°F . definitely accelerate mortality in young *G. tachinoides*, and in both species when they are $3\frac{1}{2}$ – $5\frac{1}{2}$ weeks old, but young *G. submorsitans* are not affected; (b) when the maximum temperature attained is 105°F ., marked mortality is produced among individuals 8–15 days old of both species; and (c) at maximums of 106°F . all tsetse succumb. (N.B.—These results can only claim to be suggestive, since neither the duration of the exposure nor the humidity have been kept constant; however, they indicate the effect of hot days and suggest approximately the degree of maximum temperature required to affect tsetse at different ages.)

Effect upon Longevity of the High Maximum Temperatures of the Late Dry Season (fig. 2).

This section deals with a special investigation into the effect upon longevity of the very high maximum temperatures recorded in April and early May. Nine

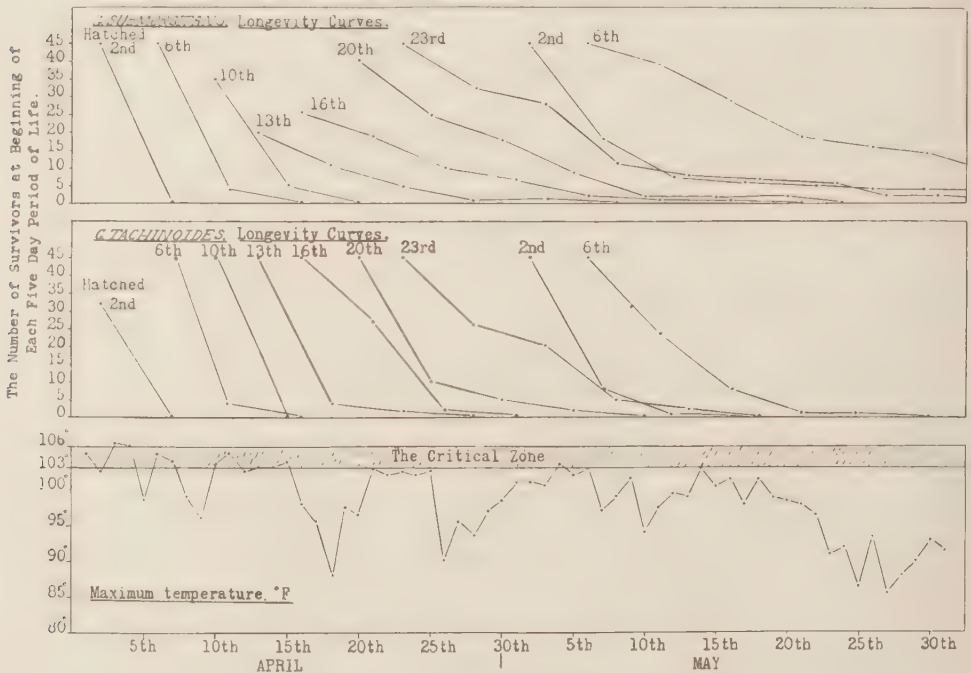


Fig. 2. The effect of the high maximum temperatures of the late dry season upon the longevity of *G. submorsitans* and *G. tachinoides*.

batches, each usually composed of 45 freshly emerged fly, were placed in the grass hut at intervals throughout this period. Deaths were noted daily and longevity expressed as the number of fly surviving at the beginning of each five-day period of life, so that the curves are comparable with those in fig. 1. The results from fig. 1 suggested that maximum temperatures lying between 103°F . and 106°F . had an adverse effect upon the flies, and so this critical temperature zone has been inserted in fig. 2.

Detailed examination of fig. 2 :—

1. *Hatched 2nd April.* Fly in this batch had to contend with maximum temperatures of 106° and 106·5°F. during their first five-day period of life, but none survived it.
2. *Hatched 6th and 10th.* A maximum of 105°F. was recorded. Individuals of neither species could survive as long as 10 days.
3. *Hatched 13th.* Highest temperature 103·5 F.; a few *G. submorsitans* survived 20 days, but no *G. tachinoides* reached 15 days.
4. *Hatched 16th.* Highest temperature 103 F.; some *G. submorsitans* survived 30 days, but no *G. tachinoides* reached 15 days.
5. *Hatched 20th.* The maximum temperature of 103 F. on 21st April seriously affected young *G. tachinoides*, but not young *G. submorsitans*.
6. *Hatched 23rd.* The maximum temperature of 103·5 F. on 4th May produced a premature mortality among many fly of both species; they were in the 10–15 day age-group at the time.
7. *Hatched 2nd May.* The maximum of 103·5 F. produced a great mortality among the young flies of both species (*cf.* No. 5 where 103°F. had no effect upon young *G. submorsitans*).
8. *Hatched 6th.* The maximum temperature of 103 F. on 6th and 14th May had no adverse effect upon *G. submorsitans*, either when just hatched (6th May) or when 8 days old (14th May); however, *G. tachinoides* was influenced at both stages.

Examination of fig. 2 has suggested that (a) a daily maximum temperature of 105°F. very seriously affects the longevity of both species; (b) *G. tachinoides* is more susceptible to a high maximum temperature than is *G. submorsitans*; and (c) a maximum temperature of 103 F. will start a definite increase in the mortality of *G. tachinoides*, but *G. submorsitans* does not start to be affected until a temperature of 103·5°F. has been recorded.

Effect of High Maximum Shade Temperature upon Young Fly.

Attention is now paid to the possibility that on these hot days humidity, or some other factor, may have a greater influence than temperature upon fly longevity.

During April and early May, daily batches, usually of 15 newly hatched and recently fed tsetse of each species, were collected and placed in the grass hut, where meteorological conditions were recorded. Deaths were entered on the following morning, and the results of each day's experiment have been collected in Table I, where they have been arranged in ascending order of maximum temperatures; when several days yielded the same maximum, these have been arranged according to the duration of the exposure to that temperature. As the initial number of flies was not always constant at 15, results are expressed as percentages, but owing to the small numbers employed anything less than 15 per cent. is probably of no significance unless repeated consistently.

Examination of Table I :—

The influence of the meteorological factors will be dealt with separately :—

1. Maximum Temperatures.

- | | |
|------------|---|
| 95°–102°F. | No effect upon the mortality of young fly of either species. |
| 102·5°F. | Possibly occasional weakly individuals of both species die more rapidly because of the heat. |
| 103°F. | No further or more pronounced mortality among <i>G. submorsitans</i> , but the mortality among <i>G. tachinoides</i> is definitely increased at this temperature, especially if it is of long duration. |

TABLE I.

Meteorological Conditions on Days of High Maximum Shade Temperature, and their Effect upon freshly emerged G. submorsitans and G. tachinoides.

Max. temp. °F.	Temperature		G. submorsitans		G. tachinoides		Saturation Deficit at time of max. temp. (in millibars)	Humidity Percentage at time of max. temp.	Evaporation for the 24 hours (in ccs.)
	Duration of max. temp. in mins.	No. of hours with temp. over 100°F.	No. of flies used	Percentage dead next morning	No. of flies used	Percentage dead next morning			
95.5°	mins. 60	hrs. 0	8	Per cent. 0	15	Per cent. 0	mb. 41.31	Per cent. 30	ccs. 43
96.0°	5	0	15	0	15	0	37.25	35	27
96.5°	30	0	11	0	15	0	51.20	15	56
97.0°	10	0	15	0	15	0	35.22	41	
97.5°	60	0	15	0	15	0	42.33	30	47
98.0°	10	0	10	0	15	7	43.01	30	47
99.0°	5	0	15	0	15	0	53.51	15	20
100.5°	60	2	15	0	15	0	51.30	28	
101.0°	45	2½	15	0	15	7	52.15	22	
101.0°	120	2¼	15	0	15	0	51.13	24	
102.0°	40	2	15	7	15	0	50.80	26	50
102.0°	80	3	15	0	15	0	49.44	28	44
102.0°	100	3¾	15	13	15	7	44.02	36	
102.5°	30	4	15	13	15	0	53.51	23	52
102.5°	120	4	0		15	0	51.13	28	33
102.5°	180	4½	16	6	15	13	56.55	19	52
103.0°	15	4¼	15	0	15	13	58.41	17	59
103.0°	50	3	15	7	15	20	47.07	34	
103.0°	70	4¾	14	14	15	13	57.57	20	53
103.0°	120	5	15	0	15	73	60.96	15	65
103.5°	15	4½	8	12	15	40	55.88	23	53
103.5°	45	4¾	11	27	15	40	61.63	15	53
103.5°	120	5	15	33	15	40	59.94	18	
104.0°	5	5½	15	40	15	47	63.33	14	55
104.8°	120	6¼	9	33	15	73	68.24	9	63
105.0°	30	5	15	53	15	73	62.31	17	52
105.0°	100	6	15	47	15	100	65.36	14	62
106.0°	60	6½	15	100	11	100	68.74	12	78
106.5°	45	6½	15	100	7	100	69.76	11	72

- 103.5 F. *G. submorsitans* is only affected by long exposures to this temperature, whereas *G. tachinoides* is affected by even short exposures.
- 104–104.8 F. When exposed to such temperatures only 33–53 per cent. of *G. submorsitans* are dead by the next morning, whereas from 47–73 per cent. of *G. tachinoides* have succumbed.
- 105°F. 47–53 per cent. of *G. submorsitans* die, irrespective of the duration of exposure, whereas 73–100 per cent. of *G. tachinoides* die, depending upon the length of exposure.
- 106°–106.5°F. 100 per cent. deaths among both species.

2. Saturation Deficiency, Relative Humidity, and Evaporation.

An examination of the data for these three different factors suggests that though undoubtedly heavy mortality occurs under conditions of very low humidity and very high evaporation, none of these factors would appear to be directly responsible for the excessive mortality on very hot days. If the data for saturation deficiency or evaporation be grouped in ascending order, or the humidity data in descending order, it will be found that there is not the same degree of positive or negative correlation with the mortality percentages, as exists between rising maximum temperature and rising mortality, within the critical zone. Laboratory experiments by Buxton & Lewis (1934) showed that humidity had but little effect upon the thermal death point.

Examination of Table I suggests that (a) the increased mortality among young flies upon very hot days is due to the maximum temperature having reached a critical zone which lies between 103°F. and 106°F., and neither humidity nor evaporation are believed to have any direct effect upon this mortality; (b) *G. tachinoides* is slightly more susceptible to high temperature than *G. submorsitans*, and also more susceptible to the duration of the exposure.

Comparative Susceptibility of Old and Young Flies to High Maximum Temperatures.

TABLE II.

The difference in effects upon young and old G. tachinoides of high maximum temperatures.

Age			No. of flies used	Deaths	Death rate	Conditions
					Per cent.	
0–10 days ...	...	...	55	16	29	Kept in laboratory; temperature never over 100°F.
10–11 days	...	...	39	19	49	Exposed in grass house for the day
Control (0–1 day)...	...	...	15	0	0	Max. temp. 102.5°F. for 80 mins.
11–12 days	...	...	20	6	30	Exposed in grass house for the day
Control (0–1 day)	...	...	15	0	0	Max. temp. 102.0°F. for 40 mins.

In fig. 1 there was evidence showing that certain maximum temperatures which would kill off old tsetse had no effect upon freshly emerged individuals; having found from Table I the degree of maximum temperature needed to produce abnormal mortality among freshly emerged individuals, it became desirable to ascertain the degree of temperature required to affect older flies adversely. Unfortunately only *G. tachinoides* were available for the following experiment:—

Fifty-five freshly emerged *G. tachinoides* were set on one side in the laboratory until they were 10 days old, by which time only 16, or 29 per cent., had died (see

Table II) ; hence, under the relatively cool laboratory conditions, where the temperature never rose above 100° F., there was a 29 per cent. mortality in a period of 10 days. Having been offered food the 39 survivors were exposed on their tenth day of life in the grass hut, where the maximum temperature rose to 102·5° F. for 80 minutes ; by the next morning 49 per cent. were dead, but out of a control of 15 newly hatched and fed *G. tachinoides*, none were dead.

The second day's exposure of the 20 survivors (now 11 days old) produced a maximum temperature of 102° F. for 40 minutes, which was followed by a 30 per cent. mortality, but again there were no deaths among a fresh batch of newly-hatched control flies.

It was shown in Table I that freshly emerged *G. tachinoides* start to be affected by a maximum of 103° F., but it has been seen in Table II that with *G. tachinoides* which are 10–12 days old a temperature of 102° F. will produce a 30 per cent. mortality ; hence freshly emerged flies of this species have a greater resistance than older flies to high maximum temperatures.

General Summary.

Newly Hatched Tsetse (0–1 day old).

1. Neither species is affected by daily maximum temperatures of 95–102° F.
2. Possibly the death of any weakly tsetse is accelerated by a temperature of 102·5° F.
3. The critical zone for *G. tachinoides* is 103° to 105° F., but at the latter temperature 100 per cent. mortality is only assured if this maximum lasts for about 100 minutes.
4. The critical zone for *G. submorsitans* is 103·5° to 105° F.
5. If maintained for 60 minutes, 106° F. assures 100 per cent. mortality among young flies of both species.

Old Tsetse (over 10 days old).

6. The critical zone for *G. tachinoides* is 102° to 105·5° F.
7. The critical zone for *G. submorsitans* is 102·5° to 106° F.
8. The sudden increase in mortality among tsetse upon very hot days would appear to be directly due to the maximum temperature having entered the critical zone, and not to excessively low humidity or very high evaporation.
9. The critical zone for old flies starts at about 1° F. lower than for newly hatched flies.
10. *G. tachinoides* is rather more susceptible to high maximum temperatures than is *G. submorsitans* ; results also suggest that *G. tachinoides* cannot withstand an exposure of long duration at high temperatures as well as *G. submorsitans*.

General Discussion.

The only other data available for comparison with the above results are those recently published by Buxton & Lewis (1934) ; they were working with the same species of tsetse, collected from the same district, but their results are not truly comparable with the writer's because their work was carried out under strictly "experimental" conditions, whereas the writer attempted to reproduce more "natural" conditions.

In their investigation young tsetse were taken from normal room temperature and were plunged into a high temperature with an unaltering humidity for periods

of either one or three hours, and finally were transferred into room temperature, where they were left for 24 hours, after which deaths were recorded.

In the writer's experiments young tsetse, having been given the opportunity of feeding, were taken from the laboratory in the cool of the morning and were placed in the grass hut; here they were kept in open cages to experience the gradual heating up of the day, the falling humidity, and the rising evaporation; in fact they were left to face the temperature under the normal dry season climatic conditions. These fly lived each day in a temperature that was often over 100°F. for several hours before and after the maximum temperature was recorded. For instance, on the day when the maximum reached 106°F., and all the tsetse died, it took 2½ hours for the temperature to rise from 100° to 106°F., where it remained steady for one hour, and then a further 2½ hours before it fell again to 100°F. These flies had been exposed for one hour to a temperature of 106°F. and 12 per cent. humidity and all died, yet Buxton & Lewis found that the upper fatal limit for such an exposure of one hour was 111·2°F., irrespective of humidity. The discrepancy is probably due to the fact that their flies were not subjected to the high temperatures that precede and succeed the period of maximum temperature under natural conditions.

When they subjected young fed *G. tachinoides* to high temperature for three hours instead of one, their results agreed almost exactly with those of the writer. They found that with exposure for as long as three hours, humidity ceased to be of any importance, and that at 102·6°F. only 13-20 per cent. of the flies died, but at 104·7°F. there was a 100 per cent. mortality. (The writer placed the critical zone for young *G. tachinoides* as lying between 103°F. and 105°F.)

Professor Buxton has pointed out to the writer that even though his investigation was carried out under relatively natural conditions (when compared with their purely experimental technique) yet the fly were incapable of indulging in extensive flights during the period of exposure, nor could they obtain a further feed of blood at the time should they have wanted it. This suggestion that under the influence of high temperature tsetse might be compelled to feed several times a day is one that needs investigation. Buxton & Lewis (1934) showed that the tsetse is one of those insects that can cool itself by evaporation, since it can resist a higher temperature in dry air than in wet, providing that the exposure only lasts for one or two hours; however, Professor Buxton has tentatively suggested to the writer that if the fly could command a plentiful supply of water by feeding on blood several times a day in the hot weather, it might be possible for the insect to survive higher temperatures. Under normal conditions a fly that has already had a large feed of blood in the morning would be still very replete some four hours later and would not take another feed; however, this might not hold good under conditions of very high temperature.

Buxton & Lewis also made some experiments upon unfed, newly hatched *G. tachinoides*, but owing to the large number of deaths among the controls the experiment was unsatisfactory; however, the fatal temperature seemed about 1·8°F. lower than for old flies. It will be remembered that the writer concluded that young flies were less susceptible to high temperature than old flies; the difference in results is probably due to the fact that the newly hatched tsetse used by these workers were not allowed their first feed of blood before being subjected to high temperatures.

Comparing the data collected by Buxton & Lewis with those of the writer, and making allowances for the great difference in technique, there is a surprising amount of agreement. If it is desired to apply their data to the problem in the field, then their results for an exposure of three hours are far more valuable than those for a short, sudden exposure of one hour. Laboratory experiments of this sort would certainly have more direct bearing upon the field problem if they were planned after a preliminary examination of the natural climatic conditions including those prevailing immediately before and after the period of maximum temperature.

Practical Application of the Results of the Experiments.

For seven months the climate has been studied in three different parts of this district :—

1. In the grass hut under the shade of a Cassia tree near the laboratory.
2. In open, hard-pan country which forms a wet season feeding-ground for the fly, but which is evacuated during the heat of the late dry season.
3. In the dense riverine forest into which tsetse retreat during the hot weather.

No conclusions can be drawn for several years from this investigation, but up to date the climate within the grass hut has been almost identical with that in the open, hard-pan country.

During those months of the late dry season when longevity is curtailed (see fig. 1) and fly die very rapidly in the grass hut, the open hard-pan country is evacuated by fly, which is not surprising, since shade temperatures up to 109°F. have been recorded there this year; even in the shade of the small clumps of thickets that occur in this open country there are many days when tsetse would be killed by high temperature alone. Even more interesting is the climate within a patch of heavy riverine forest which affords sanctuary to the tsetse in the hot weather; here conditions are far more equable, but even so on one day a shade temperature of 104°F. was recorded, only 2 F. below the upper fatal limit for both species (as found experimentally). Admitted the temperature was not so high in certain microclimates that were examined, but no evidence has yet been obtained to show that fly will utilise these sites, which being mostly on the ground should render gorged or pregnant tsetse an easy prey to predatory insects.

Even allowing for the maximum temperature in the microclimates to be a few degrees lower than in a Stevenson screen, one cannot help speculating as to whether the removal of the belt of thicket that usually surrounds the margins of patches of rain forest would not be sufficient to destroy the insulation of these fly sanctuaries; the harmattan wind would be allowed to enter, increasing evaporation and finally desiccating the floor of the forest, until possibly the shade temperature within would be sufficiently close to that of the open hard-pan country to ensure destruction of the concentrated fly population. Among the microclimates examined, those which have shown appreciably lower temperatures have all been on the ground and under shelter, where evaporation from the soil surface presumably produces a cooling effect. Should the natural thicket wind-breaks be removed, it is possible that the wind would dry up the forest floor to such an extent that these cooler microclimates would cease to exist before the end of the hot weather.

This side of the investigation is still in its infancy, but enough has been said to show that the determination of the degree of daily maximum temperature that will prove fatal to tsetse is a matter of more than academic interest.

In a statistical analysis of the climatic factors influencing the density of *G. morsitans* in Tanganyika Territory, the writer showed that fly density was correlated with saturation deficiency and evaporation, but not directly with temperature (Nash 1933 b); however, it must be pointed out that in that part of East Africa, where the shade temperature seldom went above 94°F., the possibility never arose of the daily maximum temperature reaching the upper fatal limit for *G. morsitans*.

Conclusions.

It has been shown that in open country the degree of shade temperature obtained on very hot days is above the upper fatal limit for *G. submorsitans* and *G. tachinoides*; this alone would account for its evacuation by fly in the dry season. In patches of dense riverine forest into which tsetse retreat in the hot weather the daily maximum temperatures are considerably lower, but even so they must be dangerously near

the critical zone for these insects, and, even allowing for the microclimates, tsetse can only survive the hottest days by a very narrow margin. These results suggest the possibility that a slight modification of the vegetation in the fly sanctuaries might render the forest incapable of affording the protection required by *Glossina* at this season.

This paper would not be complete without mention of the valuable assistance of Mallam Ibrahim, who is in charge of the longevity experiment.

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SOME NOTES ON THE BIOLOGY AND PHYSIOLOGY OF THE SHEEP BLOWFLY, *LUCILIA SERICATA*, MEIG.

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1. Introduction.

The following observations relate to the various internal processes which occur in the first few days of life of the adult fly, *Lucilia sericata*, Meig. The growth of the adult fat-body and ovaries is studied in relation to diet and to the abdominal air-sacs, about whose functions a new hypothesis is stated.

I am indebted to the Agricultural Research Council for a grant which defrayed the cost of this investigation.

2. The Young Adult.

It is well known that flies of the Muscid type emerge from the puparium in a greatly shrunken form called the "walker" stage by Graham-Smith (1919), who describes the process of emergence in detail. The "walker" rapidly increases in size, taking on the form of the perfect insect before the chitinous sclerites harden and assume their characteristic coloration. This increase in size occurs within a few minutes of emergence and is brought about by the "walker" rapidly swallowing air, which passes, at first, into the anterior region of the midgut and later into the crop (fig. 1, *b*). If a ligature is made around the proboscis, neck or waist of a freshly emerged "walker," the insect fails to expand and dies within several hours. In the newly expanded fly the chitinous sclerites are still soft, but soon harden rapidly and assume their characteristic green colour.

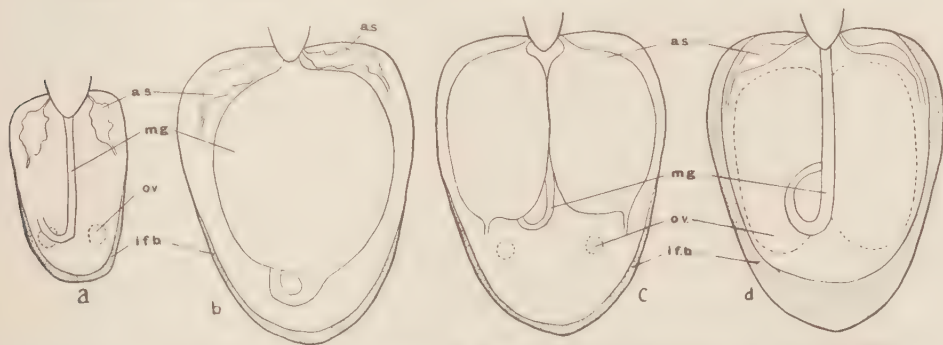


Fig. 1. Diagrammatic representation of growth in the abdomen: *a*, just emerged; *b*, after 5 minutes; *c*, after 10 hours; *d*, fully fed for 6 days. *a.s.* air-sac; *m.g.* midgut; *ov.* ovary; *i.f.b.* imaginal fat-body.

One of the characteristic structures of the Muscid fly is a pair of large air-sacs lying in the anterior portion of the abdomen; these communicate anteriorly with the small air-sacs of the thorax, posteriorly with the abdominal tracheae. They are open to the exterior through the first pair of abdominal spiracles. In the freshly emerged "walker" the abdominal air-sacs are completely collapsed (fig. 1, *a*), but in a fly one day old they are full of air and occupy much space in the abdomen (fig. 1, *c*). These air-sacs commence to fill with air about 2 hours after emergence and are fully expanded in 8-10 hours, at 30 C. Ligaturing the proboscis and anus

does not interfere greatly with the expansion of the air-sacs, so the air probably diffuses out of the mid-gut to the atmosphere *via* the blood, as shown by Eidmann (1924) for many insects. As the air diffuses away a slight negative pressure develops in the abdomen, since the sclerites are now hardened and cannot take up their former wrinkled state. To equalise the external and internal pressure, air enters the air-sacs through the first pair of abdominal spiracles. Thus, as the air diffuses out of the midgut, air enters the abdominal air-sacs. If the first pair of abdominal spiracles is waxed, air enters slowly from the rest of the tracheal system; but if all the abdominal spiracles are waxed, the abdomen often presents a collapsed appearance and little air is found in the air-sacs and none in the midgut after 10 hours.

The increase in volume brought about by the mechanism described above is most striking, and it is instructive to measure this increase. This was done by dropping batches of ten "walkers" and of ten fully expanded flies, emerged from a number of uniformly sized puparia, into a small glass overflow cylinder and measuring the overflow into a 1 cc. pipette graduated in 1/100ths cc. Absolute alcohol was used as the displacement fluid, because it has a low specific gravity and fully expanded flies are quite submerged. The percentage increase in volume is given in Table I, the experiments being carried out in duplicate.

TABLE I.
Percentage Increase in Volume of Flies after Emergence.

		Males	Females
		115	125
		118	141
Mean	...	117	133

3. Increase in Weight of Flies fed on various Diets.

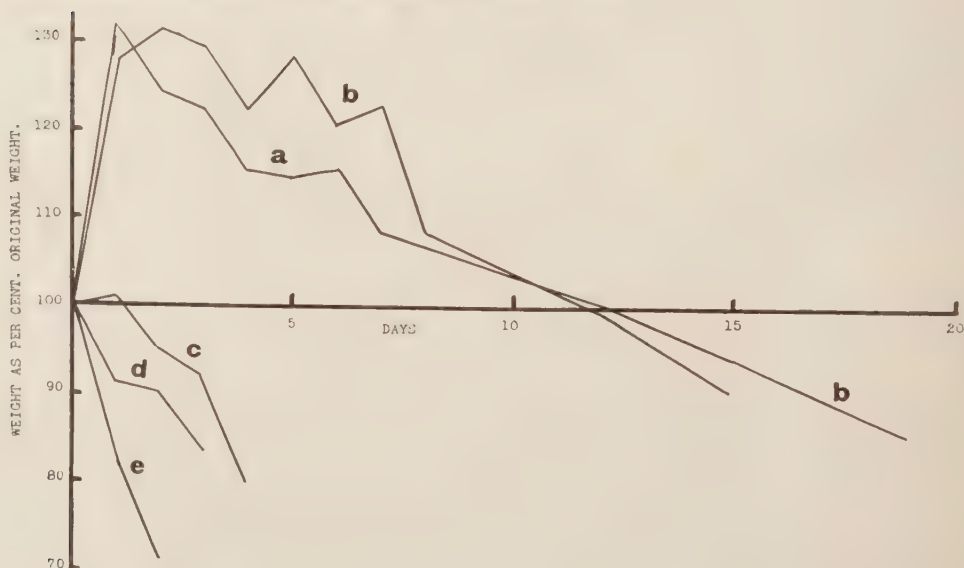


Fig. 2. Growth of males on various diets, based on 20 flies: *a*, meat, sugar and water; *b*, sugar and water; *c*, meat and water; *d*, water alone; *e*, unfed.

The natural food of *Lucilia* in nature is carrion, nectar, damaged fruit and possibly water. In the laboratory, a diet of meat, sugar and water is found to be adequate. Cousin (1932), Mackerras & Freney (1933) have shown that the female fly requires at least one meal of protein before eggs can be laid, but the male does not require protein for the development of spermatozoa. Figs. 2 and 3 show the increase in weight of males and females upon several diets at 23°C. As would be expected, no increase in weight occurs in flies fed on water alone (*d*), but they lose weight less rapidly than starved flies (*e*). No increase in weight occurs in flies fed on a diet of meat (muscle) and water (*c*), though the flies live longer and lose weight more slowly than those fed on water (*d*). Meat is evidently a poor source of nourishment.

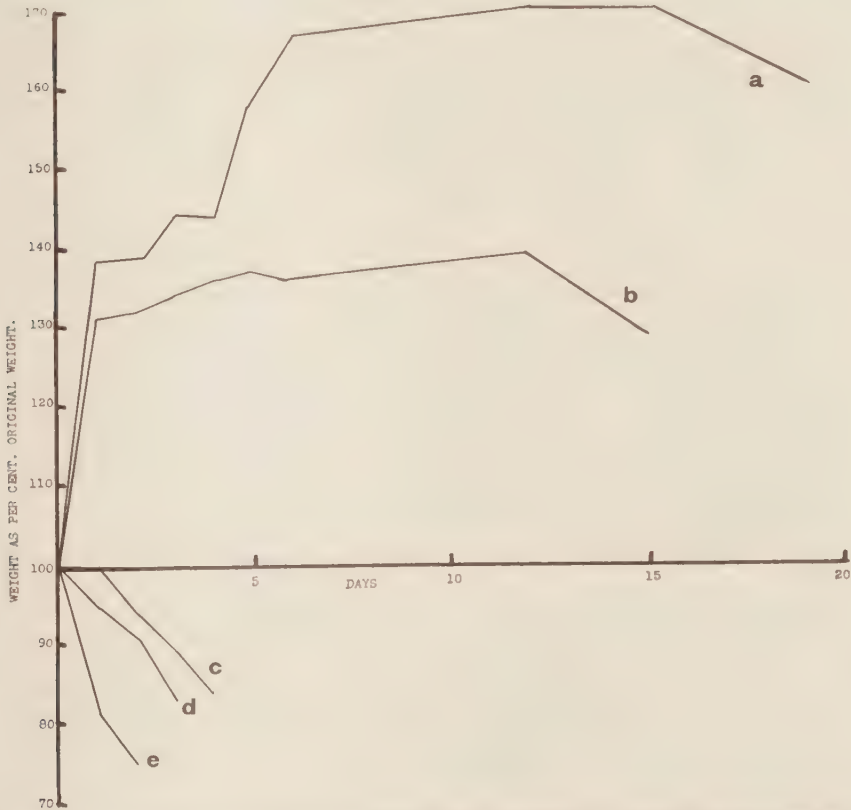


Fig. 3. Growth of females on various diets, based on 20 flies : *a*, meat, sugar and water ; *b*, sugar and water ; *c*, meat and water ; *d*, water alone ; *e*, unfed.

When fed on sugar and water (*b*) both males and females increase in weight very rapidly for the first day. The males then lose weight until they die, while the females slowly increase in weight for a few days and then decrease in weight until they die. Males fed on a complete diet of meat, sugar and water (*a*) increase in weight as much as those fed on sugar and water and lose weight at about the same rate, although they live for a longer time. Females fed on a complete diet (*a*) increase in weight rapidly at first then more slowly until the fourth day, when another rapid increase occurs, reaching a maximum on the sixth day. This second period of rapid increase in weight is clearly due to the development of the ovaries which occurs during this

time, since Table III shows that little development occurs in the ovaries during the first three days. Thus from emergence to the second day twenty females increased in weight by 254 mgs. and from the second to the sixth day by 185 mgs.; their ovaries when dissected out weighed 206 mgs.

Marked changes also occur in the percentage dry weight throughout the life of the adult. On non-growing diets, *i.e.*, water alone (*d*), and meat and water (*c*), both males and females decrease in percentage dry weight (fig. 4). On the other hand if flies are fed on growing diets, *i.e.*, sugar and water (*b*), and meat, sugar and water (*a*), the percentage dry weight rapidly increases in both males and females for the first two days. Flies fed on sugar and water attain a much higher percentage dry weight than flies fed on meat, sugar and water, also, on each diet, the females attain a slightly higher dry weight than the males. On a diet of sugar and water the percentage dry weights remain constant for about three days in the case of the male and about six days in the case of the female. They then decrease steadily until death occurs on the fifteenth day. Similar changes occur in flies fed on a complete diet, but they are not so marked.

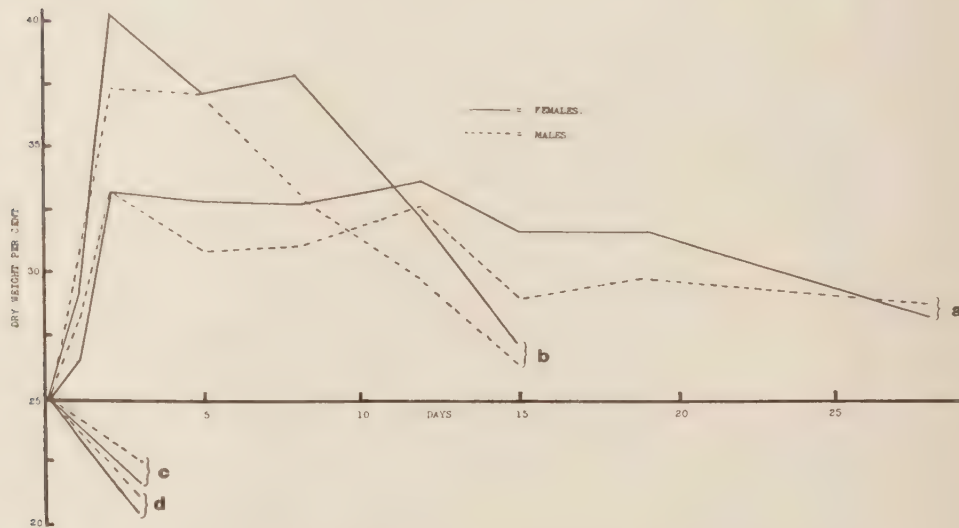


Fig. 4. Changes in percentage dry weight of flies fed on various diets: *a*, meat, sugar and water; *b*, sugar and water; *c*, meat and water; *d*, water alone.

4. Histological Changes during the Growth Period.

The changes which occur during the growth period concern the final disappearance of the pupal fat-body cells in the young imago, an increase in size of the imaginal fat-body, and the growth of the ovaries. No growth in size occurs in the testes. The following observations were carried out upon flies kept in a constant temperature room at 23°C. Most of the time these flies were kept in total darkness, but it is not thought that lack of light invalidates the results obtained, for the following reasons. The effect of light upon the feeding of starved flies is nil: males increased in weight by 70 per cent. in darkness and by 72 per cent. in daylight, females increased in weight by 102 per cent. in both cases, the flies being allowed to feed for eight hours on a complete diet. The prematuration period of six days is similar to that recorded by Mackerras (1933) for flies kept at 20–22°C. with artificial light.

The pupal fat-body consists of numerous more or less spherical cells packed tightly between the organs of the abdomen. These cells do not cohere to each other

to form a definitive tissue and when dissected from the abdomen disperse freely in the surrounding fluid. There is no doubt that these cells are derived from the pupal fat-body as found by Perez (1910) for *Calliphora*. Sections of these cells show a small central nucleus surrounded by numerous eosinophile granules (fig. 5, *a*). The nature of these granules is of interest. They are of a highly viscid nature; on crushing the cells under a cover glass the granules do not disperse but remain somewhat flattened *in situ*; great pressure is needed to make them cohere with each other. The granules are insoluble in strong sodium bicarbonate, and sulphuric and nitric acids, but are fairly soluble in strong sodium hydroxide. Their proteid nature is shown by positive biuret and xanthoproteic reactions and precipitation by mercuric nitrate. A negative result is obtained with Millon's reagent.



Fig. 5. Histology of the imaginal fat-body: *a*, pupal fat-body cell containing proteid inclusions; *b*—*f*, imaginal fat-body cells; *b*, just emerged; *c*, fed sugar and water 5 days; *d*, fed meat, sugar and water 5 days; *e*, fed meat and water 3 days; *f*, fed water 3 days.

Whether these proteid granules have any special function it is difficult to say, but the following observations suggest that they are transferred to the imaginal fat-body, which grows rapidly during the first few days of imaginal life. Table II, A and B, shows the time of disappearance of the pupal fat-body cells in males and females fed on different diets. A — sign indicates absence of the pupal fat-body cells, a \pm sign very few cells present, a + sign fairly numerous, and a ++ sign very numerous; but even the latter sign represents a considerable diminution in the amount originally present in the just emerged fly.

TABLE II.

*Disappearance of and Relative Amounts of Pupal Fat-body Cells in :—*A. *The Male.*

Day	2	3	4
Fed meat, sugar, water ...	±	—	—
Fed sugar, water ...	±	±	—
Fed meat, water ...	++	+	all dead
Fed water ...	++	+	all dead

B. *The Female.*

Day	2	3	4
Fed meat, sugar, water ...	±	—	—
Fed sugar, water ...	+	—	—
Fed meat, water ...	++	—	all dead
Fed water ...	++	—	all dead

These results indicate that flies fed on diets which allow of growth utilise the inclusions of the pupal fat-body cells more rapidly than those fed on non-growing diets. The fact that the cells have disappeared in the females by the third day and are still present in males fed on certain diets suggests that the inclusions of the cells might be utilised by the growing ovaries. However, no significant growth of the ovaries could be observed in females fed on incomplete diets (Table III).

TABLE III.

Diameter of Ovaries on the Third Day of Flies on various Diets.

Initial diameter in unfed fly ...	0.8 mm.
Fed meat, sugar, water ...	1.3 mm.
Fed sugar, water ...	0.9 „
Fed meat, water ...	0.9 „
Fed water ...	0.9 „

Perez (1910) records that in *Calliphora erythrocephala* the pupal fat-body cells are destroyed in the imago by leucocytes. In *Lucilia sericata* the leucocytes attack the cells only when their granular inclusions have largely disappeared. A similar difference between the two species has been found in the rôle of the leucocytes during histolysis of the larval muscle; in *Calliphora* leucocytes attack the histologically unchanged muscle, in *Lucilia* they attack only muscle which is completely degenerated.

The imaginal fat-body (fig. 5, b-f) is a well marked tissue located chiefly in the posterior abdominal segments just below the hypodermis. Each cell is multinuclear

with a vacuolate cytoplasm. The cells also contain as an integral part one or more "oenocytes" as they are termed by Perez (1910). These possess a homogeneous cytoplasm and are binucleate. They differ completely from the larval oenocytes, which are segmentally arranged, much larger in size, uninucleate, and possess a finely reticulate cytoplasm. In the newly emerged fly the imaginal fat-body is not very extensive, occupying considerably less volume than the pupal fat cells (fig. 1, *a, b*). When the fly is fed on a complete diet, the imaginal fat-body grows rapidly, both inwards and forwards, replacing the disappearing pupal fat-cells and displacing some of the air from the abdominal air-sacs. Flies dissected on the third day show the air-sacs to be greatly reduced in volume compared with their original volume in the unfed fly. Flies fed on an incomplete diet of sugar and water show a similar growth of the imaginal fat-body. The cells of the fat-body of flies fed on the above diets show interesting differences. When the flies are fed on sugar and water the cells contain much larger vacuoles than those of flies fed on meat, sugar and water, also the amount of cytoplasm present is much less in flies fed on water and sugar (fig. 4, *c, d*). No growth of the imaginal fat-body occurs in flies fed on water alone or meat and water. On the contrary, the fat-body shrinks in size, the cells lose their vacuoles and the cytoplasm becomes homogeneous and densely staining, so much so that it becomes difficult to distinguish the oenocytes from the general cytoplasm.

Table III shows that on a complete diet the ovaries increase in size but little during the first few days of adult life, so during this period the increase in weight of the fly is principally due to the growth of the fat-body. Growth of the ovaries takes place most rapidly between the fourth and sixth days. At this time the abdomen becomes distended with eggs; the ova, formerly round, become elongate and occupy all the available space, compressing the abdominal air-sacs so that these contain very little air indeed.

The foregoing facts lead to a consideration of the function of the abdominal air-sacs in flies of this type.

TABLE IV.

Rate of Consumption of Dry Matter in fed and unfed Flies, kept at 25°C. and 40 per cent. Relative Humidity for 12 hours. (Each reading represents consumption of dry matter in 20 flies.)

				Females		
				a	b	Males
				mgs.	mgs.	mgs.
Unfed flies	...	...	...	12.2	14.3	11.2
Fed flies	...	...	...	83.4	87.0	57.6

5. Significance of the Abdominal Air-sacs.

Several views are held with regard to the function of the air-sacs in insects. These views are summarised by Wigglesworth (1931), who regards the two main functions of the air-sacs as being (*a*) a means of lowering the specific gravity of the insect; and (*b*) to increase the volume of tidal air by providing regions in the tracheal system which can be readily compressed and distended.

In *Lucilia*, the forward growth of the imaginal fat-body and ovaries and the consequent compression of the abdominal air-sacs lead to a progressive increase in the specific gravity of the fly and to a diminution of the volume of tidal air during the prematuration period. Also it is evident that the tracheae alone are able to supply a sufficiency of oxygen for respiration, since in fully fed flies about to oviposit,

the rate of metabolism is about seven times that of unfed flies (Table IV), *i.e.*, the rate of metabolism is greatest when the air-sacs contain but little air. Hence it is clear that the abdominal air-sacs are not greatly concerned in regulating the specific gravity of the insect, nor in ensuring an adequate supply of oxygen to the tissues.

Recalling the sequence of events occurring after emergence from the puparium, it would appear that the main function of the air-sacs, in flies of the Muscid type, is to maintain the increased volume of the young imago and so provide ample space in the abdomen for the rapidly growing fat-body and ovaries. The fact that the emerging female fly increases in volume more than the male (Table I) fits in well with this hypothesis, since the male only increases in weight by 30 per cent., while the female increases in weight by 70 per cent., the difference representing the weight of the ovaries.

6. Summary.

1. The increase in weight of flies of both sexes is followed on several diets. Unfed flies and flies fed on water alone or on meat and water lose weight. Males fed on meat, sugar and water, or on sugar and water, increase in weight rapidly during the first day of adult life and then lose weight until they die. Females fed on sugar and water increase in weight rapidly for the first day and then more slowly until the twelfth day, when they commence to lose weight until death occurs. A similar rapid increase in weight on the first day occurs in females fed on meat, sugar and water, but a second period of rapid increase occurs between the fourth and sixth days. The first period corresponds to the growth of the imaginal fat-body and the second to the growth of the ovaries. The percentage dry weight of flies fed on meat, sugar and water and on sugar and water increases rapidly at first but then decreases slowly until death occurs.

2. The disappearance of the pupal fat-body cells and the growth of the imaginal fat-body on several diets is described. It is suggested that the inclusions of the pupal fat-body cells are transferred to the rapidly growing imaginal fat-body.

3. The hypothesis is put forward that the abdominal air-sacs in flies of the Muscid type have but little respiratory function and are chiefly concerned in

- (a) preserving the increased volume of the newly-emerged fly;
- (b) providing ample space within the abdomen for growth of the imaginal fat-body in the male and for the fat-body and ovaries in the female, both of which organs increase greatly in size.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st October and 31st December, 1934 :—

AGRICULTURAL OFFICER, QUETTA :—14 Coleoptera, 2 Parasitic Hymenoptera, 6 Lepidoptera, and 2 Rhynchota ; from Baluchistan.

Mr. W. ALLAN, Government Entomologist :—100 Parasitic Hymenoptera ; from Northern Rhodesia.

Mr. A. M. ALTON :—10 Parasitic Hymenoptera ; from South Africa.

Mr. D. J. ATKINSON :—27 Parasitic Hymenoptera ; from Burma.

Dr. H. F. BARNES, Rothamsted Experimental Station :—2 Parasitic Hymenoptera ; from Canada.

Mr. E. BALLARD, Government Entomologist :—1 species of Aphidae ; from Palestine.

Prof. W. H. BRITAIN, Macdonald College, Quebec :—5 *Tabanus*, 15 other Diptera, 770 Coleoptera, 10 Parasitic Hymenoptera, 129 other Hymenoptera, 196 Rhynchota and 10 larvae, 3 Cicadid exuviae, 33 Orthoptera, and 23 Planipennia ; from Canada.

Prof. P. A. BUXTON, London School of Tropical Medicine :—12 Staphylinidae ; from China.

Mr. H. F. CARTER :—35 Tabanidae and 63 other Diptera ; from Ceylon.

CHIEF ENTOMOLOGIST, PRETORIA :—50 Parasitic Hymenoptera ; from South Africa.

Mr. S. F. CHIU :—4 Diptera, 50 Parasitic Hymenoptera, 3 Rhynchota, and 8 Orthoptera ; from China.

Mr. G. H. CORBETT, Government Entomologist :—41 Diptera, 30 Coleoptera, 84 Parasitic Hymenoptera, 79 other Hymenoptera, 17 Lepidoptera, 200 Isoptera, and 22 Rhynchota ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—739 Coleoptera, 2 ♂ Coccidae, and 576 other Rhynchota ; from East Africa.

Dr. A. DA COSTA LIMA :—18 Curculionidae ; from Brazil.

Mr. G. S. COTTFRELL, Government Entomologist :—2 species of Aleurodidae ; from the Gold Coast.

Mr. A. CUTHBERTSON, Assistant Entomologist :—89 Diptera and 15 Coleoptera ; from Southern Rhodesia.

Dr. J. DESHUSSES :—13 Parasitic Hymenoptera ; from Switzerland.

DIRECTOR OF AGRICULTURE, NORTH BORNEO :—194 Orthoptera ; from British North Borneo.

DIRECTOR OF AGRICULTURE, SEYCHELLES :—3 Lepidoptera and 15 early stages, and 1 species of Coccidae ; from the Seychelles.

DIRECTOR OF PUBLIC WORKS, LAGOS :—100 Isoptera ; from Nigeria.

Mr. L. H. DUNN :—3 Polycetenidae and 50 Mites ; from Panama.

FARMERS WEEKLY :—2 Diptera and 20 early stages, and 3 Vespidae ; from England.

Prof. J. C. FAURE :—2 Coleoptera and 283 Orthoptera ; from South Africa.

Mr. J. L. FROGGATT, Government Entomologist :—36 Diptera, 103 Coleoptera, 8 Parasitic Hymenoptera, 17 other Hymenoptera, 23 Lepidoptera, 13 Rhynchota, 5 Orthoptera, 3 Planipennia, and 5 Odonata ; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—69 Coleoptera ; from the United Provinces, India.

Mr. S. GARTHSIDE :—1 species of Eriophyidae ; from England.

Mr. F. D. GOLDING, Government Entomologist :—10 Lepidoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—5 Parasitic Hymenoptera ; from South India.

Prof. G. GRANDI :—231 Parasitic Hymenoptera and 300 cocoons ; from Italy.

Mr. W. GREENWOOD :—5 Curculionidae and 78 Lepidoptera ; from Fiji.

Mr. E. HARGREAVES, Government Entomologist :—15 Diptera, 64 Coleoptera and 4 ootheca, 230 Parasitic Hymenoptera, 10 other Hymenoptera, 112 Lepidoptera, 16 Thysanoptera, 10 Rhynchota, 13 Orthoptera, and 17 Trichoptera ; from Sierra Leone.

Mr. H. HARGREAVES, Government Entomologist :—91 Diptera, 118 Coleoptera, 96 Hymenoptera, and 69 Lepidoptera ; from Uganda.

Mr. W. V. HARRIS, Entomologist :—9 Lepidoptera, 1 species of Coccidae, and 43 other Rhynchota ; from Tanganyika Territory.

Mr. K. J. HAYWARD :—12 Diptera ; from the Argentine.

Mr. G. F. HILL, Entomologist :—2 Hymenoptera ; from Australia.

Mr. W. E. H. HODSON :—24 Parasitic Hymenoptera and 27 Lepidopterous larvae ; from England.

IMPERIAL INSTITUTE OF VETERINARY RESEARCH, MUKTESAR :—20 Mites ; from the United Provinces, India.

INDIAN LAC RESEARCH INSTITUTE :—4 Parasitic Hymenoptera ; from Bihar, India.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—74 Coleoptera, 32 Lepidoptera, and 17 Rhynchota ; from the Netherlands Indies.

Mr. W. F. JEPSON :—20 Hymenoptera ; from Madagascar and Rodrigues.

Prof. J. N. JHAVERI :—1 species of Mite ; from Poona, India.

Mr. H. B. JOHNSTON :—314 Coleoptera, 4 Rhynchota, 568 Orthoptera, and 2 Dermaptera ; from Uganda.

Mr. M. A. LIEFTINCK :—30 Parasitic Hymenoptera ; from Java.

Messrs. G. LOCKLEY and P. WARD :—350 Parasitic Hymenoptera ; from England.

Mr. H. MANEVAL :—8 Parasitic Hymenoptera ; from France.

Dr. L. MASI :—11 Parasitic Hymenoptera ; from Egypt.

Mr. G. A. MAVROMOUSTAKIS :—15 Orthoptera ; from Cyprus.

Dr. D. MILLER, Cawthron Institute :—29 Parasitic Hymenoptera ; from New Zealand.

Mlle. G. MONTET :—300 Parasitic Hymenoptera and 100 cocoons ; from Europe.

Mr. H. M. MORRIS, Government Entomologist :—1 Spider ; from Cyprus.

MUCAMBO COCOA ESTATES :—4 Coleoptera and 15 Rhynchota ; from Brazil.

MUSÉE DU CONGO BELGE, Tervueren :—42 Parasitic Hymenoptera ; from the Belgian Congo.

MUSEUM NATIONAL D'HISTOIRE NATURELLE, PARIS :—3 Chalcididae ; from France.

Dr. J. G. MYERS :—1 species of Coccidae ; from Jamaica.

Messrs. H. T. PAGDEN and R. A. LEVER, Government Entomologists :—37 Culicidae, 15 Tabanidae, 409 other Diptera, 451 Coleoptera, 220 Parasitic Hymenoptera, 2,329 other Hymenoptera, 201 Lepidoptera, 900 Isoptera, 11 Thysanoptera, 12 species of Coccidae, 331 other Rhynchota, 100 Psocidae, 29 Orthoptera, 2 Odonata, 20 Collembola, 50 Mites, 5 Spiders, 7 Chelifera, 3 Millipedes, and 7 Woodlice ; from the Solomon Islands.

Mr. A. PAILLOT :—94 Parasitic Hymenoptera ; from France.

Dr. H. PRIESNER :—20 Parasitic Hymenoptera ; from Egypt.

Dr. P. REGNIER :—70 Rhynchota and 66 Orthoptera ; from Morocco.

Mr. A. H. RITCHIE, Government Entomologist :—84 Coleoptera, 514 Parasitic Hymenoptera and 52 cocoons, 150 other Hymenoptera, 611 Lepidoptera and 4 pupa cases, and 50 Rhynchota ; from Tanganyika Territory.

ROYAL VICTORIA DOCKS, DEPTFORD :—8 Dipterous early stages and 3 Bruchidae ; from England.

Mr. T. A. RUSSELL, Plant Pathologist :—100 Parasitic Hymenoptera, 13 Rhynchota, and 1 species of Mite ; from Bermuda.

NIHAT SHEVKET BEY :—5 Diptera, 38 Coleoptera, 80 Parasitic Hymenoptera, and 9 other Hymenoptera ; from Asiatic Turkey.

Mr. O. SCHNEIDER-ORELLI :—65 Parasitic Hymenoptera ; from Switzerland.

SELANGOR MUSEUM :—233 Coleoptera ; from Borneo.

Mr. H. W. SIMMONDS, Government Entomologist :—1 Moth ; from Fiji.

Mr. F. A. SQUIRE, Government Entomologist :—5 Tabanidae, 46 other Diptera, 27 Coleoptera, 13 Parasitic Hymenoptera and 16 slide preparations, 16 other Hymenoptera, 2 Lepidoptera, 20 Isoptera, 2 species of Coccidae, 28 other Rhynchota, and 3 Millipedes ; from British Guiana.

Mr. T. V. SUBRAMANIAM, Entomologist :—7 Membracidae and 6 Gryllidae parasitised by Strepsiptera, and 200 Parasitic Hymenoptera ; from Mysore, India.

Mr. D. C. SWAN :—5 Curculionidae, 11 Parasitic Hymenoptera, 10 cocoons, and 3 galls ; from Australia.

Mr. N. TELENGA :—19 Braconidae and 10 cocoons ; from Russia.

Dr. A. L. TONNOIR :—5 *Phlebotomus* ; from New South Wales.

Mr. T. L. TSOU :—135 Orthoptera ; from China.

Mr. R. W. E. TUCKER, Government Entomologist :—100 Diptera and 18 Parasitic Hymenoptera ; from Barbados.

UNITED STATES NATIONAL MUSEUM, WASHINGTON :—9 Parasitic Hymenoptera ; from India ; and 28 Parasitic Hymenoptera ; from North America.

UNIVERSITY MUSEUM OF ZOOLOGY, CAMBRIDGE :—87 Parasitic Hymenoptera ; from England.

Mr. G. C. VARLEY :—108 Parasitic Hymenoptera and 7 cocoons ; from England.

Mr. A. C. W. WAGNER :—300 Braconidae ; from Germany.

Mr. G. WEIDNER :—6 Parasitic Hymenoptera ; from Germany.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—81 Culicidae, 2 Tabanidae, 210 *Phlebotomus*, 53 other Diptera, and 218 Coleoptera ; from the Sudan.

Mr. W. E. WHITEHEAD :—5 Anoplura and 18 slides of Mallophaga ; from Canada.

Dr. F. ZACHER :—6 Coleoptera and 83 Parasitic Hymenoptera ; from Egypt.

MOSQUITO NOTES.—XII.

By F. W. EDWARDS. *W*

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I. SOME NEW RECORDS FROM FIJI.

***Uranotaenia painei*, sp. n.**

♂.—*Head* clothed with blackish scales, many erect and forked. Proboscis dark, slightly shorter than abdomen but not thickened. *Thorax* rather dark ochreous-brown, uniform in tint, except that the postnotum is darker, without ornamentation of any kind; bristles and scales dark. No flat scales above wing-root, and no scales at all on front margin of mesonotum or on posterior pronotal lobes; a patch of small flat scales on upper part of sternopleura which are difficult to detect as they are of the same colour as the integument. *Abdomen* entirely dark brown both above and below. *Legs* uniformly dark brown, devoid of special features in ♂; first tarsal segment of fore and mid legs about as long as tibia, that of hind legs slightly longer than tibia. *Wings* dark, venation and scaling normal; length 2.5 mm.

Larva.—*Head* moderately dark. Antennae short, spicular; shaft-hair single and well beyond middle, apical bristles normal. Frontal hairs: *A* 5-branched, *B* and *C* moderately stout, single, finely barbed, *C* well behind and internal to *B*; *d* split into several fine branches from middle, internal to and slightly in front of *C*; *e* long and single, placed far back. Clypeal spines very short and thick, pointed. Mentum almost equilaterally triangular, with about 12 teeth on each side. *Thorax* with some of the long hairs double or triple, including hairs 1, 4 and 7 of prothorax, and several of the pleural hairs of meso- and metathorax; hairs 1–3 of prothorax set in rather large chitinous plates, which are rather close together (in *U. colocasiae*, the other Fijian species of the genus, hairs 1–7 of prothorax are all single, and 1–3 are set in quite small plates, which are far apart). *Abdomen* with strong lateral hairs on the first two segments only (in *U. colocasiae* the lateral hairs are strong on each of segments 1–7). *Eighth segment* with the subsiphonal tuft very large, composed of about 8 long plumose branches; plate large, extending upwards nearly to meet its fellow of the opposite side, with 10–12 scales bordering the lower half, these scales with long fine fringe all round, the tips rounded. Anal segment ringed, much longer above than deep; caudal hairs both double, also lateral hair and most of those in the small brush. *Siphon* four times as long as its breadth at the base, slightly tapering on distal third; a large tuft of 8–10 slightly plumose branches at a little beyond the middle; pecten extending to or slightly beyond insertion of tuft, composed of 23–30 very short, closely set scales which consist mainly of fringe around a somewhat triangular base. Anal papillae about as long as saddle, sharply pointed.

FIJI: Salialevu, Taveuni; larvae obtained in small rock-pools in a stream, iii.1934; the larvae "appeared only to be present in those pools which contained stagnant water with cast skins of a crab" (*R. W. Paine*).

The adult of this new species is very much like *U. obscura*, Edw., and *U. papua*, Brug, from both of which it is well distinguished by the absence of flat scales on the anterior margin of the mesonotum and on the posterior pronotal lobes.* It is also very similar to *U. colocasiae*, Edw., but is much smaller and with the thorax less dark. The larva shows most of the typical features of *Uranotaenia*, and is totally different from that of *U. colocasiae*, and also quite distinct in several respects from that of *U. papua*; the form of comb-plate and comb will distinguish it from some other somewhat similar species, such as the Indian *U. recondita*, Edw.

***Aëdes (Stegomyia) scutellaris* var. *horrescens*, nov.**

♀.—Closely resembles var. *pseudoscutellaris* in ornamentation, no constant difference being discoverable; the median white line of the thorax is perhaps broader (except posteriorly, where it tapers to a point), and the white lateral abdominal marks are visible dorsally as small spots on each of segments 2-7 (in var. *pseudoscutellaris* segment 2 is usually, and segment 3 very frequently, entirely dark in dorsal view). All other markings quite as in var. *pseudoscutellaris*, and showing similar slight variation: third segment of front and middle tarsi perhaps more frequently showing some white scales at the base than in var. *pseudoscutellaris*.

♂.—Differs from var. *pseudoscutellaris* in having more or less definite though seldom complete dorsal white bands on some or all of segments 2-6. Hypopygium somewhat intermediate between those of var. *pseudoscutellaris* and var. *hebridens* (compare figures in Bull. Ent. Res., **17**, p. 102); basal lobe with a row of hairs towards the tip only, those actually at the tip not markedly longer than the others; style almost as slender as in var. *pseudoscutellaris*.

Larva.—Differs from that of var. *pseudoscutellaris* in being very much more hairy, as well as in several other respects, as follows:—

var. *horrescens*.

Antennae longer, stouter at base; spicules rather numerous, shaft-hair double.

Frontal hairs *B* and *C* double.

Lateral hair and two pairs of hairs on lower surface of head strongly developed, with 6-8 plumose branches.

Dorsal and ventral hairs of thorax and abdomen strongly developed, most of them forming large tufts of 8-12 plumose branches.

Inner caudal hair and lateral hair of anal segment each 4-branched.

Pecten of 12-20 rather closely-set teeth.

Posterior margin of saddle strongly spinose.

Upper pair of anal papillae about as long as saddle, lower pair about half as long.

var. *pseudoscutellaris*.

Antennae shorter, cylindrical; no spicules, shaft-hair single and more slender.

Frontal hairs *B* and *C* single.

Lateral hair and all hairs on lower surface of head small, with not more than 2-3 simple branches.

Dorsal and ventral hairs of thorax and abdomen all small and weak, mostly with 3-5 simple branches.

Inner caudal hair and lateral hair of anal segment each 2-branched.

Pecten of about 10-16 teeth which are less closely-set.

Posterior margin of saddle weakly spinose.

Upper pair of anal papillae about twice as long as saddle, lower pair not much shorter than upper.

* Brug noted the presence of these scales when describing *U. papua*, and I find on re-examining the specimens of *U. obscura* in the British Museum that they are present in that species also.

Fiji: Ura, Taveuni, iv. 1934; larvae found in tree-holes in forest (R. W. Paine): 6 ♂ (including type), 7 ♀, with isolated larval and pupal skins, also preserved larvae and 4 ♂ reared from the same batch, presented to the British Museum by the collector. Also further material, including 1 ♂ 3 ♀ with isolated larval skins, reared from tree-holes in forest at 550 ft., Taveuni, x. 1933.

In October 1933 Mr. Paine sent adults and larvae of *A. scutellaris* obtained from three different sources on Taveuni: some from tree-holes in the forest; some from barrels put out in a coconut plantation for the breeding of *Megarhinus*, some distance from the forest; and some from coconut husks, split open for copra-cutting, in the coconut plantation near to the barrels. Regarding this material Mr. Paine wrote:

"As far as I can make out there are two rather well-marked varieties of *A. variegatus* larvae: viz., a hairy form with short anal gills, and straight antennae, and a less hairy form with longer anal gills and slightly curved antennae. I had thought that the hairy variety was confined to the forests, and the other to more open and 'domestic' situations. But you will see that amongst the material from the barrels both forms are represented, although the less hairy form is the more usual, and a few specimens seem to be rather intermediate, while in the coconut husk material there is also an occasional hairy form. . . . In 1927 I collected larvae of the hairy form from a hole in a coconut trunk at Nabavatu in the Lau, or eastern group of the Fiji islands. . . . It is possible that the hairy form does not occur in Viti Levu. I have never found it there, but then I have not bred *A. variegatus* from the forests near Suva: only on Taveuni."

Examination of this material showed that the males of the two forms could be separated by small differences in the hypopygium, but the material was scarcely adequate for description, and Mr. Paine therefore obtained the ample fresh material on which the above description of the new form is based.

The two larvae are so strikingly different, even to the naked eye, that without rearing them one would assume them to belong to completely different species; doubt might well arise as to whether the hairy form was a *Stegomyia*, owing to the spicular antennae, a feature not found in any member of the subgenus except the aberrant *A. (S.) vittatus*. On the other hand the distinctions between the adults are if anything even slighter than between the various other known varieties of *A. scutellaris*; consequently I prefer to consider the new form as another variety rather than a distinct species. The great differences between these two larvae are the more surprising because the larvae of several other forms are rather closely similar; I have studied larvae of the type form, of var. *tongae*, and of var. *hebrideus*, and find them to agree with those of var. *pseudoscutellaris* in nearly all the details noted above, differing chiefly in the relative length of the anal papillae.

It is noteworthy that, so far as our present knowledge goes, throughout the greater part of the range of *A. scutellaris* only one variety is found in any one area; only in Fiji do two forms occur together. It is possible that var. *horrescens* is the native Fiji form, and that var. *pseudoscutellaris* has been more recently introduced, perhaps from Samoa.

***Aedes (Finlaya) kochi*, Dön., and *A. (F.) samoana*, Grünb.**

In 1926 (Bull. Ent. Res., 17, p. 103) I gave a synopsis of the species of the *kochi* group of the subgenus *Finlaya*, treating *A. (F.) samoana*, Grünb., as a variety of *A. (F.) kochi*, Dön. The material then available of some of the forms was rather scanty, and did not include any males of typical *A. kochi*. The deficiency has now been supplied by Mr. R. W. Paine, who has sent a short series of both sexes from Fiji, the females are similar in all respects to those from New Guinea in the British Museum, and the form is presumably typical *kochi*.

Comparison of mounted hypopygia of specimens from Fiji and Samoa shows that very considerable differences exist, so much so as to suggest that the two should be treated as distinct species rather than as subspecies. The diagnostic characters are as follows :

A. kochi : Coxite rather broad, not narrowed distally, with a large patch of hairs at the base, amongst which is a long, bent and twisted bristle ; a second small patch of short hairs on inner side beyond middle, and near this towards the sternal side a group of only four or five longer, flattened bristly hairs or very narrow scales. Style about as long as coxite, somewhat curved beyond middle, with a very long, curved terminal appendage and one long hair close to the tip.

A. samoana : Coxite narrower, especially on distal half, with a large patch of hairs as in *A. kochi*, but the bent bristle very much shorter and quite inconspicuous ; the second group of hairs, at middle of coxite, is scarcely indicated, but on the other hand there is a large scale-tuft towards the sternal side, comprising 10-12 very long, broad, pointed scales in two rows. Style only about two-thirds as long as coxite, straight, with the terminal appendage somewhat shorter and straighter than in *A. kochi*, and without a subterminal hair.

As the distinctions between the adults of these two forms are so very pronounced, I naturally expected to find comparable differences in the larvae, but a close comparison of the larval skins sent by Mr. Paine with larvae of *A. samoana* from Upolu has failed to reveal any character by which the two may be distinguished. This is the more surprising since Brug has shown that the larva of the closely-related *A. (F). poecilus*, Theo., differs in several very obvious features.

The Fijian specimens of *A. kochi* were collected as larvae from the leaf-axils of *Colocasia indica* in or near forest at Nabavatu, Vanuabalavu, and at Bucalevu, Taveuni. Regarding their occurrence Mr. Paine writes :

" This is, I think, the first occasion on which the early stages of *A. kochi* have been found in Fiji. I was surprised to find them in *C. indica* (they were not in *C. esculenta* on Vanuabalavu, and I think never breed in the latter species) as I have searched leaf-axils of that plant many times and found only *U. colocasiae*. After searching many plants of *C. indica* on Taveuni I found *A. kochi* in one leaf-axil only, whereas *U. colocasiae*, and even *Aedes variegatus*, were abundant. . . . I have my suspicions that *U. colocasiae* competes with *A. kochi* to the detriment of the latter, and that were *U. colocasiae* introduced to Samoa it would ultimately drive *A. kochi* out of *C. esculenta* altogether."

II. SOME NEW RECORDS FROM HONG KONG.

Anopheles fluviatilis, James.

A series of 7♂ 5♀ was received from Dr. R. B. Jackson in April 1935. These specimens agree closely with Indian examples of the species, the distinctions noted by Christophers (*Fauna Brit. Ind.*, Anoph., p. 211) from *A. minimus* holding good. — *A. fluviatilis* has not hitherto been found west of Tonkin.

Uranotaenia jacksoni, sp. n.

♂.—Closely resembles *U. stricklandi*, Barr., and *U. bicolor*, Leic., notably in having the thorax mainly yellowish, without flat scales above wing-root ; well-marked pale basal bands on abdominal segments 2-7 ; dark legs, without special secondary sexual features, and dark-scaled wings with the upper fork-cell very short. Differs from one or both of these species as follows : *Head* with the decumbent scales mostly rather light brown, with a narrow border of creamy scales round eyes ; very few erect forked scales. *Thorax* apparently without any flat scales on front margin

of mesonotum (a few such scales are present in *U. stricklandi*). Only about 6 sternopleural hairs. Dark markings of pleurae much less extensive; only the extreme upper corner of the sternopleura darkened, brownish, posterior pronotum and postspiracular area also darkened; remainder of pleurae, including whole of mesepimeron, pale yellow (in *U. stricklandi* the mesepimeron is wholly dark; in *U. bicolor* it is dark above and below, pale in the middle; in both these species there is a dark area on the middle of the sternopleura).

HONG KONG: 1 ♂ captured by bank of stream, 1934 (Dr. R. B. Jackson).

Culex infantulus, Edw.

Isolated larval skins received from Dr. R. B. Jackson agree in almost all respects with the larva of *C. minutissimus* as described by Barraud, but the presence of a dark ring in the middle of the siphon is not constant; it is very obvious in some specimens, but in two others, from Pokfulam, it is absent. There is apparently no difference in the adults; males reared from both forms of larva have numerous small tubercles on the terminal portion of the lateral plates of the phallosome (the presence of these tubercles distinguishes *C. infantulus* from *C. minutissimus*).

Culex shebbearei, Barraud.

Four males with isolated larval skins from Shing Mun, Hong Kong, 27.iii.1934 (Dr. R. B. Jackson), agree with Indian material, except that the larval siphon is rather stouter (index about 5, after allowing for flattening, instead of about 6), and the antennae is not quite so long. The frontal and siphonal hairs of the larva are much as in *C. viridiventer*.

Culex jacksoni, Edw.

When describing this species recently (in Barraud, Fauna Brit. Ind., Culicidae, p. 452) I attempted to distinguish the adult from that of *C. mimeticus* by the uniformly reddish-brown colour of the mesonotal scales. Further specimens (1 ♂ 2 ♀, with larval skins) received from Dr. Jackson show that this distinction does not hold good; in all these specimens the mesonotum has a distinct mottling of pale scales, as in *C. mimeticus*. I am unable to point out any other adult characters by which these two may be distinguished, although the larvae appear distinct.

III. NEW SPECIES OF AËDES (FINLAYA) FROM CHINA AND MADAGASCAR.

Aëdes (Finlaya) fengi, sp. n.

Head with scales on upper surface narrow and mostly white. Proboscis and palpi entirely dark; palpi in ♂ slightly shorter than proboscis, slightly swollen and distinctly hairy on last two segments. Torus black, clothed with white scales. *Thorax* with blackish integument. Mesonotum in ♀ clothed mainly with dark brown scales; a patch of whitish scales above each wing-root, connected with a pair of small patches of whitish scales in middle; some narrow white scales round front border, and three rather narrow stripes of creamy-white scales on anterior half, these stripes not very sharply defined and close together, the median stripe narrower than the other two. Mesonotum of ♂ with the white scales much more numerous, obscuring the pattern and leaving a small dark patch towards each side in front. Scales on anterior and posterior pronotal lobes in both sexes all broad, flat and white. Scutellar scales narrow and white. *Abdomen* all black above; tergites with basal lateral white patches; sternites dark apically. *Hypopygium*: Coxites rather long and narrow with small patch of hairs at base but without special scales; style slender, tapering, about half as long as coxite, with simple terminal claw; harpago with stem rather stout

and nearly straight, bearing three strong hairs and a broad leaf-like appendage. *Legs* blackish; front and middle femora almost all dark in front and without distinct knee-spots; hind femora white both in front and behind on basal three-fifths, with an indistinct dark dorsal line, tip rather narrowly white; front tibiae narrowly white at base beneath, remaining tibiae all dark; all tarsi with narrow white rings at bases of first two segments, last three segments all dark, except for two or three white scales at base of third hind tarsal segment. Wings entirely dark-scaled, length about 3-3.5 mm.

CENTRAL CHINA: Muganshan, Chekiang, viii. 1932 (*Lan Chou Feng*), 1 ♂ 1 ♀ (types) reared from larvae in bamboo stumps; Hangechow, Chekiang (*Feng-Swen Li*), 1 ♂ 1 ♀. *Types* presented to the British Museum by the collector.

The presence of only two narrow white rings on the hind tarsi distinguishes this species from all others of the subgenus known in Asia. In ornamentation it perhaps most closely resembles *A. (F.) uncinatus*, Edw., which has only a single pale tarsal ring and also differs in having a narrow black ring at the base of the hind femur and the three pale stripes on the mesonotum of the female less definite and wider apart. *A. (F.) japonicus*, Theo. (*eucleptes*, Dyar) and *A. (F.) koreicus*, Edw., are in some respects similar, but have the pale scales of the thorax golden in colour and different in arrangement, and three or four hind tarsal rings.

The female from Hangechow differs in having no median pale line on the mesonotum.

***Aedes (Finlaya) monetus*, sp. n.**

♀.—Allied to *A. (F.) longipalpis*, Grünb., and *A. (F.) fulgens*, Edw., which it resembles in its black and silver head and thorax, with the posterior pronotal lobes densely covered with round flat silver scales and with a double row of similar scales running the whole length of the mesonotum and forking in front of the scutellum, and in its blue-black abdomen and legs. Differs from both the African species in having the tarsi entirely dark; no silvery scales on middle or hind femora, and hind femora creamy-white on the basal half or more, with a dark dorsal line; no white at base of hind tibia beneath; two patches of silvery scales on each side of mesonotum, one immediately in front of wing-base (as in the other two species), the second further forwards, connected with the silvery area of the posterior pronotum; abdominal tergites 6 and 7 with complete but irregular silvery bands. Palpi only one-fifth as long as proboscis, and therefore shorter than in either of the African species (in the West African *A. longipalpis* the palpi are about one-third, in the East African *A. fulgens* about two-thirds as long as the proboscis). Middle lobe of scutellum as in *A. fulgens* entirely covered with silver scales.

MADAGASCAR: Maevatanane, 21-22.xii. 1923, 2 ♀ in house (*Dr. W. A. Lamborn*).

The mosquito fauna of Madagascar as at present known consists mainly of species which also occur on the mainland of Africa. The discovery of this very distinct species suggests that the endemic element of the fauna may prove to be larger than has been supposed when the tree-hole breeding species have been investigated.

IV. OCCURRENCE OF *AÈDES CABALLUS*, THEO., IN PERSIA.

Among a small lot of mosquitos recently sent to the British Museum by Dr. S. L. Brug were two males and two females of an *Aedes (Ochlerotatus)* from Persia. These specimens formed part of a series reared from larvae found in a swamp and in a well at Djask (Persia) by Dr. Slotboorn in April 1932.

On account of the rather close resemblance of the hypopygium of the male to that of *A. mariae*, Dr. Brug thought the Persian specimens might perhaps represent an extreme variation of that species, in spite of considerable differences in coloration.

However, a careful study of them shows that they are undoubtedly *A. (O.) caballus*, Theo., a species hitherto known only from South and East Africa. *A. caballus* may be distinguished very readily from all other Palaearctic species by the coloration of the hind tarsi, the second and third segments having narrow white basal rings, while the fourth and fifth segments are entirely or almost entirely dark (a few white scales are sometimes present at the base of the fourth segment). The abdominal ornamentation is not unlike that of *A. mariae* or *A. dorsalis*, and on hypopygial characters the species would certainly be placed in the *dorsalis* group; the only obvious hypopygial distinction from *A. mariae* is that the stem of the claspette is not narrowed at the tip and is without obvious hairs.

The occurrence of this African species in Persia is surprising, but it may be widely distributed in the Near East, though hitherto overlooked. It has long been known that some Mediterranean mosquitos (e.g., *Culex theileri*, Theo., and *Theobaldia longiareolata*, Mcq.) extend through East Africa to the Cape, and *A. caballus* provides a further instance of either the same or the converse phenomenon.

V. NEW AFRICAN CULICINES.

Megarhinus aeneus var. **viridibasis**, nov.

♂.—Resembles typical *M. aeneus*, differing chiefly as follows:—Scales on pleurae almost all silvery white, with only a small patch of golden scales below wing-root and an almost equally small patch on lower part of sternopleura (scales on posterior pronotum golden as in *M. aeneus*). First three abdominal segments almost entirely green-scaled, contrasting with the remainder, which are purple.

UGANDA: Kampala, 6.x.32, type ♀; Soroti, 7.viii.31, 1♀ (*G. H. E. Hopkins*). Presented to British Museum by collector.

In typical *M. aeneus*, of Nigeria and Sierra Leone, there is a large patch of golden or coppery scales occupying almost the lower half of the sternopleura, and the abdomen is either entirely purple above or with a variable amount of green scaling on the first two tergites.

Ficalbia (Mimomyia) hispida, Theo.

It is now known that this species is one of a group of closely-allied forms which are distinguishable more readily in the larval than in the adult stage. Mr. G. H. E. Hopkins has distinguished three quite distinct larvae of this group in Uganda, and these will be described in the forthcoming monograph on the mosquitos of the Ethiopian Region to be published by the Trustees of the British Museum. The adult of one of these three was recently described by me as *F. perplexens*; a second is described in the subsequent text.

Among the specimens in the British Museum still regarded as belonging to the species *F. hispida* some rather obvious differences in adult colouring are to be found, and as these differences may be more significant than has hitherto been supposed the forms are described below under varietal names. All agree in the following respects:—Flat scales of head pale yellowish. Posterior pronotal lobes largely or entirely pale, and some at least of the bristles on their posterior margin yellow. Abdominal tergites either basally banded or with lateral pale spots only. Hind tarsi dark to extreme base. First segment of flagellum of female antenna almost or quite three times as long as second. Ninth tergite of male hypopygium broader than long, with a group of 3–5 hairs at each hinder corner.

Type form.

Postnotum mainly yellowish, with a narrow and rather ill-defined median dark brown stripe. Pleurae entirely yellowish, without a dark spot on the anepisternite, or

such a spot is only faintly indicated. Tergites 2-7 with lateral basal triangular pale spots which are only just visible dorsally. Outer surface of hind femur largely pale.

The type was from the Sudan; specimens are in the British Museum from Uganda (Kampala only). Other specimens from the Gold Coast (Bole, 1911, *A. Ingram*) differ in having the postnotum entirely yellowish, without the median dark stripe.

var. *palustris*, Theo.

Postnotum almost wholly dark brown. Pleurae with a more or less distinct dark cloud on the anepisternite, behind the spiracle. Mesonotal integument and scales darker than in the type form. Tergites mostly with lateral spots only, but 5-7 usually with the spots larger, extending along the whole of the sides and also meeting in middle at base. Hind femur more extensively dark externally than in the type form.

Apart from the type the British Museum possesses numerous specimens from Uganda (Kampala, Entebbe and Fort Portal) also 1 ♀ from S. Rhodesia (Umtali, *A. Cuthbertson*).

var. *sunyaniensis*, nov.

Postnotum entirely dark and anepisternite with a dark spot, as in var. *palustris*, but tergites 3-7 in both sexes all with complete basal yellowish bands (tergite 2 with lateral spots only, no pale scales in middle at base). Hind femur as in the type form.

Gold Coast (Sunyani, 1915, *A. Ingram*).

***Ficalbia (Mimomyia) lacustris*, sp. n.**

Closely allied to *F. (M.) hispida*, differing as follows:—Mesonotal integument and scales almost entirely black or very dark brown, darker than the darkest specimens of *F. hispida*; posterior pronotal lobes mainly blackish, and all their bristles black (though in contrast with the general black colour of the mesonotum the pleurae are yellow, without any dark cloud on the anepisternite, and the postnotum is light brownish). Abdominal tergites 2-7 with small median as well as lateral basal pale spots (often visible only on tergite 2 in slightly shrunken specimens). First segment of flagellum of female antenna rather shorter than in *F. hispida*, not more than 2.5 times as long as second. Ninth tergite of male hypopygium longer than broad, with 3-5 bristly hairs along each side.

UGANDA: Entebbe, 10 ♂ (including type) 2 ♀, 1.ii.1931 (*G. H. E. Hopkins*); Jinja, 1 ♂ 1 ♀, viii.ix.1931 (*G. H. E. Hopkins*); Olumat, 1 ♀, 17.i.1931 (*G. L. R. Hancock*); Kampala (?), 22.v.1927, 1 ♀ (*G. L. R. Hancock*). BELGIAN CONGO: Stanleyville, 1932, 1 ♀ (*Dr. J. Schwetz*). FRENCH W. AFRICA: Fort Lamy, L. Chad, 1 ♀ (*Dr. H. Galliard*).

***Aedes (Stegomyia) bambusae*, sp. n.**

A very distinct species, differing from all other African members of the subgenus in at least two respects: (1) all the markings of the mesonotum are yellow or golden in colour, not white; and (2) there are no pale knee-spots on any of the femora. Mesonotum with a pair of yellow lyre-shaped marks, recalling those of *A. aegypti*, but with a single conspicuous yellow median line, which broadens slightly anteriorly. Abdominal tergites 2-7 with incomplete dull yellowish basal bands, 1-8 with dull white basal lateral patches. Middle femora without white spot in middle in front. Hind tibia white at base beneath. Hind tarsi with narrow white rings at bases of segments 1-3, segment 4 all white, 5 white above to a variable extent. Basal lobe of ♂ coxite with short dense hairs and several short spines.

UGANDA: between Mts. Mgahinga and Sabinio, Congo-Uganda border, and at Muko, S.W. of Kabale, both localities in bamboo-forest at about 8,000 ft. altitude,

some specimens captured, many others reared from larvae found in bamboo-stems (*F. W. Edwards* and *E. G. Gibbins*); British Museum East African Expedition.

***Aedes (Stegomyia) angustus*, sp. n.**

Very similar to *A. (S.) bambusae* as described above, but differing as follows: Thorax distinctly laterally compressed (in *A. bambusae* it is of the normal shape). Mesonotal markings more creamy-yellow in tint, the patch of scales above wing-root almost white; lyre-shaped marks not quite so broad; median stripe broader, more conspicuously widened in front. Middle femora with a small white spot in middle in front (absent in one specimen). Basal lobe of ♂ coxite with long dense hairs only, no spines.

UGANDA: in association with *A. bambusae* in both localities mentioned above. Many specimens reared (*F. W. Edwards* and *E. G. Gibbins*); British Museum East African Expedition.

***Aedes (Aedimorphus) gibbinsi*, sp. n.**

A very distinct species on account of the form of the male palpi, which differ from those of all other members of the subgenus in being slender, upturned, and almost devoid of hairs, as in the subgenus *Stegomyia*. Ornamentation of mesonotum rather distinctive: scales for the most part dark brown, but a rather broad band of golden scales on each side in front, more or less connected with a pair of golden lines on posterior half of mesonotum; in some specimens a pair of ill-defined admedian golden lines on anterior half of mesonotum; scales on scutellum and around the bare space narrow and golden. Abdominal tergites 2-7 with median basal creamy-white spots. Hypopygium showing only slight specific differences from that of *A. quasiunivittatus*, Theo. Legs black; hind tibia with a conspicuous white spot at tip.

UGANDA: between Mts. Mgahinga and Sabino, Congo-Uganda border, and in Namwamba Valley, Ruwenzori, both localities in bamboo forest at about 8,000 ft. altitude, some specimens captured, others reared from larvae in ground pools (*F. W. Edwards* and *E. G. Gibbins*); British Museum East African Expedition.

In spite of the striking difference in the form of the male palpi, this species is evidently closely allied to *C. quasiunivittatus*, Theo.

***Culex (Mochthogenes) fimbriforceps*, sp. n.**

A dark species with little or no ornamentation, resembling *C. (M.) inconspicuus*, Theo., in most respects, but differing as follows:—Head with the flat scales confined to the sides and to a narrow border round the eyes, most of the decumbent scales on the vertex being narrow and curved. Hind femora mainly whitish, with a narrow dark dorsal line which does not reach the base (in typical *C. inconspicuus* the hind femur is mainly black-scaled; in some light specimens it is pale on the outer side but dark above to the base). Hypopygium: distal portion of style slender and provided with a fine fringe (such a fringe is absent in *C. inconspicuus*); processes of style rather differently shaped; lobes of phallosome longer and more uniformly slender.

UGANDA: Jinja Road, IV.1931, 1 ♂ (type) 1 ♀ reared from pool (*G. L. R. Hancock*); Kasala Stream, viii.1910, 1 ♂ (*Col. A. D. Fraser*). BELGIAN CONGO: Stanleyville, 1927, 1 ♂ 1 ♀, in company with *C. inconspicuus* (*Dr. Mouchet*).

***Culex annulioris*, Theo., var. *major*, nov.**

Differs from typical *C. annulioris* in its larger size and abdominal markings. Wing-length in ♀ 6-6.5 mm. (in *C. annulioris*, type form, and in var. *consimilis* it is only 4-5 mm.). Abdominal tergites with distinct basal pale bands which are somewhat widened in the middle; apical lateral pale spots very small or even absent. Hypopygium not obviously differing from that of the typical form.

KENYA : Nairobi district, 1924 (*Dr. van Someren*), a series including type ♂ ; also 19.viii.1912, 1 ♀ (*T. J. Anderson*). BELGIAN CONGO : Blukura, L. Albert, 5,100 ft. (*Dr. J. Schwetzi*). UGANDA : Kabale, Kigezi district, ix.1932 (*G. H. E. Hopkins*).

***Culex calurus*, sp. n.**

A species of the *pipiens* group, very similar to other African species of the group in external appearance, but very distinct in structure of hypopygium : coxite very much swollen, the lobe scarcely prominent, undivided and placed very near base of style, the three proximal rods remarkably twisted ; style broad and of almost even width from base to tip ; ninth tergites unusually large and hairy ; paraprocts each with a group of about 9 hairs instead of the usual 4-5. Palpi of ♂ moderately hairy, scarcely longer than proboscis. Mesonotal scales mostly dark brown, the pale ones not forming a distinct pattern. Abdominal bands well defined, creamy in colour ; sternites with dark apical bands produced basally in middle. Hind femur pale outwardly to near the tip. Hind tibia with a small pale spot at tip.

KENYA : Aberdare Mts., lower slopes of Mt. Kinangop, x.1934, type ♂ in light-trap at 8,000 ft. (*F. W. Edwards*) ; 1 ♂ captured in bamboo forest at 10,000 ft. (*J. Ford*) ; British Museum East African Expedition.

The species showing most resemblance to *C. calurus* in hypopygial characters is *C. ninagongoensis*, Edw., but the two are amply distinct.

***Culex weschei*, sp. n.**

Closely related to *C. guiarti*, Blanch., the hypopygium of the male being almost if not quite identical in structure, and the antennae of the female being sub-plumose, as in *C. guiarti* and related species (*ingrami*, Edw., *schwetzi*, Edw.). Differs from *C. guiarti*, in the adult stage, chiefly as follows : Tergites 6 and 7 of abdomen with larger basal pale patches, which meet in the middle, forming more or less complete bands. Green colouring (in the dried specimens, possibly not in life) confined to base of abdomen and posterior part of thorax. Legs more extensively pale, the pale scales being yellowish in tint instead of white ; whole of middle legs (femur, tibia and tarsus) appearing yellowish when seen from behind (in *C. guiarti* the middle femora are dark above, whitish beneath, and the tibiae and tarsi are only indefinitely pale, when seen from behind) ; hind femur mainly yellowish, with a dark dorsal line on about the distal third only (in *C. guiarti* the dark dorsal line extends along the distal half or more).

GOLD COAST : Sunyani, 1915 (*Dr. A. Ingram*) type ♂ and 3 ♀ in the British Museum.

These specimens are now described as a species distinct from *C. guiarti* largely on account of well-marked differences in the larvae ; the larva of the present form was figured in a paper by Macfie & Ingram (*Bull. Ent. Res.* **7**, p. 9), while that of the true *C. guiarti* was described and figured by Ingram & Macfie (*Bull. Ent. Res.* **8**, p. 150).

I distinctly recollect that the differences in colouring from typical *C. guiarti* were observable, as described above, when the specimens were received in 1915 ; there has been no subsequent fading. The species may readily be distinguished from the somewhat similar *C. schwetzi* and *C. ingrami* by the structure of the hypopygium, and from *C. schwetzi* also by the uniformly light brownish mesonotal integument, without paler patches on the shoulders.

THE AUSTRALIAN SPECIES OF THE GENUS *PHLEBOTOMUS*.

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(PLATE I.)

Introduction.

Until about ten years ago Australia was considered to be free from the haemato-phagous Diptera of the genus *Phlebotomus*, which are found abundantly in all other regions of the earth, over one hundred species having been recorded. Mr. G. F. Hill was the first entomologist to discover in Australia a species of the *minutus* group, which he described¹ under the name of *P. queenslandi*. This species was found in Townsville, North Queensland, in a bath-room, and nine flies were secured. It has not been found again since, either there or lower down the Australian east coast, where such experienced entomologists as Drs. Bancroft, Ferguson and Mackerras, have kept a special look-out for these flies.

It fell again to the lot of Mr. Hill to discover the second Australian species; but this time it was in Canberra, F.C.T., a locality which might have been considered as the least likely in Australia to yield any *Phlebotomus*. The Federal Capital Territory is situated at an altitude of about 2,000 ft. at no considerable distance from the Australian Alps. The mean temperature in winter being 44°F. and in summer 68 F., the climate of Canberra is therefore among the most temperate of the continent; the annual rainfall is 22 inches. Since several species of *Phlebotomus* are present in Australia, where general climatic conditions would appear to be exceedingly favourable to them, it is difficult to understand why they should not be as abundant in this country as in other parts of the world, and since they have been found here in two localities, one of fairly low temperature and low rainfall and the other of high temperature and high rainfall, the factors restricting their diffusion are by no means obvious, inasmuch as where they do occur, they are at times present in fairly large numbers.

The females of the second species (described below as *P. brevifilis*) were found inside a house, flying round the electric light at night. Following upon Mr. Hill's discovery I ascertained that this species was also frequenting my own house, as several females were found dead in the inverted bowl-shade of the electric light of the living room. Males were not secured on these occasions, which made me conclude that the females were attracted inside the house not so much by the light, as by the hope of securing a meal of blood.

A couple of years later, among a lot of *Psychoda* collected at my request by Miss K. English in Yass, N.S.W., I found a specimen of *Phlebotomus*, and since then, thanks to Miss English's perseverance, a great many specimens were secured from that locality, which is only 40 miles distant from Canberra and enjoys similar climatic conditions.

Three forms were found in the material obtained from Yass: *P. brevifilis*, a species of the erect-haired group which had been previously found at Canberra, and two others of the *minutus* group, one of which is so closely related to *P. queenslandi*, Hill, that it cannot very well be considered as a distinct species.

After a close search for the breeding-ground of these flies, which were mostly caught inside the house round the light or on the panes of a glassed-in verandah, Miss English located it in a rubble-pit receiving the waste water from the house; this

pit was not completely closed, as is usually the case, and in placing a net over the opening she was able to secure many specimens as they emerged.

At my suggestion Miss English endeavoured to ascertain whether any of these species could feed on human blood. Her experiment was quite successful with the erect-haired species, which drew blood from her, whereas the other two species of the *minutus* group could not be induced to do so. All the species would, however, feed readily on lizard blood. Miss English also succeeded in breeding one species through one generation, using as a medium some soil taken from places where wood lice were congregating in large numbers.

It is a pleasure for me to acknowledge here my indebtedness to Miss English for her untiring assistance in supplying me with abundant material and even sometimes with live flies, from which the spermathecae were extracted for study. My best thanks are also due to Mr. G. F. Hill for making available to me his type material of *P. queenslandi* and his specimens of the species he discovered in Canberra.

Taxonomic Characters.

During these last ten years considerable progress has been made in the study of *Phlebotomus*, thanks chiefly to Parrot & França, Sinton, Adler & Theodor, and more recently to Nitzulescu. The first two have evolved an elaborate method of phlebotometry² whereas Adler and his associates discovered certain reliable specific characters in the structure of the buccal cavity, of the pharynx and of the spermathecae. But none of these authors has ever considered *Phlebotomus* as a part of a family of Diptera, the PSYCHODIDAE, for the description of which a terminology already existed. As a student of the whole of the family I wish to call attention here to a few discrepancies which have thus arisen. I am well aware that family rank has been claimed by Theodor for the PHLEBOTOMINAE on account of the special conformation of the mouth-parts made for sucking blood, but the recent discovery in India of *Horaiella*³, a genus which has still retained its mandibles and is also in other respects a link between *Phlebotomus* and the rest of the PSYCHODIDAE, completely invalidates this suggestion.

As regards the antennae, the paired structures found on the flagellar segments have been so far known as "spines" or "geniculate spines" in *Phlebotomus*. Feuerborn⁴ has shown that these structures are in reality sense-organs, and he has proposed for them the name of "ascoids," which is quite fitting. In the PSYCHODIDAE the ascoids may assume all sorts of shapes and are usually more developed in the male; it is the contrary in *Phlebotomus*, in which they are smaller in the male and often single, moreover as they are uniform in shape throughout the genus (with the exception of *P. troglodytes*) these organs have here very little taxonomic value, if any.

The venation of *Phlebotomus* has never been correctly interpreted by any of the Phlebotomists. In order to understand it, it is necessary to refer to *Nemopalpus*, the most primitive existing genus of the family, as well as to other fossil genera, and to study in detail the base of the wing of *Phlebotomus*. I give here (fig. 1, A, B) the wing venation of *P. queenslandi* and that of *Nemopalpus zealandiae*, in which the branching of the veins at the base, especially of the last few veins, have to be studied closely in order to understand the homology of the venation. In both cases *Cu* is a convex vein, but in *Phlebotomus* it is withdrawn right at the base of the wing, and in many species it is hardly distinguishable unless an absolutely flat mount of the wing be made. That is why so many figures depicting the venation of this genus are quite inaccurate so far as this vein is concerned.

Fig. 1, A, shows how the rest of the venation of *Phlebotomus* should be interpreted. It has been the custom to designate the various segments of the veins of importance in the taxonomy of the species by Greek letters, and although this is not a very orthodox method in dipterology I must admit that it is convenient and do not, therefore, propose to change it.

Key to the Australian Species of Phlebotomus.*Females.*

1. Hairs erect on the dorsum of the abdomen* ; spermatheca with many irregular constrictions and with a fairly wide duct (fig. 3, *d*) ; pharynx with numerous triangular teeth having the general appearance of a heavy reticulation ; buccal cavity with only a few triangular teeth (Plate I, *e*).....*brevifilis*, sp. n.
- Abdominal hairs recumbent ; spermatheca with smooth walls and narrow duct ; pharynx with rather sparse small scales or numerous long hair-like scales ; buccal cavity with a comb of very numerous fine teeth.....2
2. Pharynx with small scales giving the appearance of a slight reticulation (Plate I, *F*) ; teeth of the buccal cavity numbering about 85...*englishi*, sp. n.
- Pharynx with hairs or hair-like scales (Plate I, *b, c*)3
3. Teeth of the buccal cavity moderately numerous, about 45 in number (Plate I, *a*).....*queenslandi*, Hill
- Teeth of the buccal cavity very numerous ; 80 in number or more (Plate I, *c*) ; southern form.....*queenslandi meridionalis*, subsp. n.

Males.

1. Style of hypopygium with three spines (fig. 2, *C*), hairs on the dorsum of the abdomen erect ; filaments of the penis relatively short (fig. 2, *D*) ; buccal cavity without teeth ; pharynx with slender scales forming a fine reticulation (Plate I, *d*).....*brevifilis*, sp. n.
- Style with four spines (fig. 2, *A*) ; abdominal hairs recumbent ; buccal cavity provided with teeth ; pharynx with hairs or scales.....2
2. Pharynx hairy.....*queenslandi meridionalis*, subsp. n.
- Pharynx scaly.....3
3. Buccal cavity with about 16 teeth (Plate I, *h*).....*queenslandi*, Hill
- Buccal cavity with about 43 teeth (Plate I, *g*).....*englishi*, sp. n.

Phlebotomus queenslandi, Hill.

The eight specimens collected within a period of three days (11 to 14th January 1925) in a bath-room at Townsville and forming the type series were all kindly submitted to me by Mr. Hill for study. These specimens were mounted in Canada balsam, and no trace of the structure of the buccal cavity, pharynx or spermathecae was visible ; they were therefore all removed from the slides and remounted after further dissection and staining.

The following characters were then made out :—In the male the buccal cavity is provided with a slender comb with more or less regular teeth, whose number varies from 15 to 17 ; the pharynx has a comparatively small number of shallow scales arranged so as to give the impression of a loose and slender net (Plate I, *h*).

The measurements of the antennae are somewhat different from those given by Mr. Hill ; as can be seen from Table I, the ascoids are single and little developed. The measurements of the palpi were not given in the original description, they are II 0.066, III 0.109, IV 0.115.

The wing index δ varies very much. Through some unaccountable mistake, the figure of the wing given by Mr. Hill was inverted, so that the venation seems quite abnormal ; moreover a small flaw appears as an extra cross-vein between R_1 and R_2 .

* When all the hairs are rubbed off it is still possible to tell to which group a specimen belongs by the character of the pores ; in the case of an erect-haired species the pores are coarser and shaped like a small crater, whereas in the other group the pores are small and triangular.

The armature of the style of the hypopygium is quite characteristic of the *minutus* group; not only the four large curved spines are present in the same order, but also the internal preapical sensory bristle, as shown in fig. 2, A. The sheaths of the penis are pointed, but their apex is not sharp; it is turned a little inward and downward, the penis filaments protruding subapically on the side. The parameres do not carry any very characteristic vestiture besides the rather numerous sensory bristles, which on the underside form a group of only 3 to 5.

TABLE I.

Phlebotomus queenslandi, Hill.

		Holo- type	Allo- type	Minimum		Maximum		Average*	
		♂	♀	♂	♀	♂	♀	♂	♀
Antennae, Segt. III		·114	·135	·114	·128	·135	·135	·125	·134
	IV	·071	·078	·071	·078	·078	·078	·075	·078
	XII-XVI	·249	·249	·241	·249	·263	·284	·251	·257
Palpi, Segt. II ...		·064	·078	·064	·071	·071	·078	·067	·073
	III ...	·110	·114	·099	·114	·114	·121	·109	·119
	IV ...	·114	·121	·114	·114	·121	·121	·115	·119
Wing :	Length	1·358	1·540	1·260	1·372	1·358	1·540	1·360	1·526
	Width	·336	·406	·336	·378	·350	·406	·343	·392
	α	·168	·224	·168	·210	·196	·238	·180	·221
	β	·308	·280	·210	·280	·308	·294	·266	·284
	γ	·224	·280	·210	·280	·294	·294	·242	·284
	δ	·035	·112	·035	·084	·070	·112	·054	·098
Hind legs :	Femora	·556	·663	·530	·663	·560	·663	·548	·663
	Tibia	·666	·848	·666	·795	·715	·848	·694	·813
	Basitarsus	·345	·345	·318	·345	·345	·504	·338	·397
	Tarsi II-V	·477	·530	·477	·530	·490	·530	·481	·530
Total	...	2·044	2·386	1·991	2·333	2·110	2·545	2·061	2·403
Hypopygium :									
	Coxite	·213	—	·178	—	·220	—	·203	—
	Style	·107	—	·092	—	·107	—	·101	—
	Paramere	·163	—	·134	—	·163	—	·154	—
	Penis sheath	·107	—	·092	—	·107	—	·101	—
	Cerci	·185	—	·149	—	·185	—	·170	—
	Penis fil.	·335	—	·326	—	·355	—	·340	—
	Pumpetia	·078	—	·057	—	·078	—	·067	—

*The average measurements are not those between the maxima and minima; they have been obtained from a large number of specimens.

Female.—The pharynx is moderately widened at the posterior end where it is provided with fairly abundant, very elongate, thin scales, which could be taken for hairs were it not for the absence of pores at the point where they are inserted on the pharynx (Plate I, b). The armature of the buccal cavity consists of a comb with about 45 teeth (Plate I, a). The spermathecae are of the smooth oval type; fig. 3, c, shows that of the allotype and is depicted there somewhat wider than it really is, as the preparation of this specimen is fairly flat; also the base of this organ is crumpled, as usually happens in mounted specimens.

The relative measurements of the various parts are as in the male but somewhat larger on the whole; the wing index is less variable. The ascoids are in pairs except on segments 14 and 15, where they are single.

It is remarkable that the armature of the pharynx differs so much in the two sexes, one being scaly and the other hairy (in appearance), whereas in the two other forms of this group described below, the armature is of the same nature in both sexes. Yet as the relative measurements of all the organs are the same, I can hardly believe that all the males and all the females collected by Mr. Hill in the same room within a few days should happen to belong to different species; besides a similar difference exists also in other species, such as *P. barraudi*, Sint. In none of the three forms of the *minutus* group studied here is the pigmented area of the buccal cavity very distinct; in fact in most specimens it appears to be absent altogether, although adequate staining may sometimes bring it out.

As this species appeared to be very scarce in North Queensland and as it was first captured in a coastal town, I at one time thought that it might have been introduced by navigation; I have therefore compared it with the described species from countries in more or less close proximity to North Australia, such as the Dutch East Indies, the Philippines and the Malay Peninsula (the genus exists in New Guinea but no species has yet been described from there). The species with which it shows the greatest affinities is *P. barraudi*, Sint. 1929, from Assam, which has similar wings and buccopharyngeal armature, as well as other relative measurements. So far as I can see from the description and drawings it differs from *P. queenslandi* by the somewhat less numerous teeth (40 instead of 45) of the buccal cavity, which are arranged in a curve instead of a straight line, and by the very conspicuous pigmented area and the hair-like scales of the pharynx of the female, which have a very distinct triangular base; otherwise it agrees in everything, even in the sexual dimorphism of the pharyngeal armature, which is scaly in the male and, in appearance, hairy in the female.

The next most closely related species is *P. manganus*, Menal., from the Philippines, which has similar buccal and pharyngeal armatures but differs from *P. queenslandi* in its much broader wings, in which α is much larger than β , in the much longer hind legs and the ovoid spermatheca. According to Menalang's figure the style of the male hypopygium is devoid of the small internal median bristle, but it is easily overlooked; moreover the antennal segment III is more than twice as long as segment IV.

P. heiseri, Menal., is another Philippine species coming near to *P. queenslandi* by the structure of the pharynx and of the buccal cavity, but the venation is quite different.

A third Philippine species of the *minutus* group, *P. hitchensis*, Menal. 1930, is also related to *P. queenslandi*; however, it differs rather conspicuously from it in the relatively great length of δ and the absence of teeth or scales in the pharynx.

The type series is deposited in the collection of the Division of Economic Entomology at Canberra.

***Phlebotomus queenslandi meridionalis*, subsp. n.**

This form differs by quite constant characters from *P. queenslandi*, as given in the key to the species, but these differences, especially in the females, seem to me to have too little importance to justify the erection of a species. With exception of the greater number of teeth in the buccal cavity and the slight difference in size the females from Queensland could not be separated from those from N.S.W. There is no essential difference to be found in the shape of the spermatheca, so far as I could judge from the very limited suitable material of the typical form. A comparison between fig. 3, *A*, and fig. 3, *c*, is not conclusive, as the former is made from a rather flat preparation of preserved material, whereas the other is drawn from fresh unmounted material.

When one comes to study the males, some doubts may arise as to the validity of the view expressed above, because there is here a very characteristic difference in

the armature of the pharynx, which is scaly in the Queensland specimens and hairy in the N.S.W. ones. Yet here also the measurements are exceedingly similar, although relatively larger, as can be seen from Tables I and II, except in the average for δ ; however, this may be just as small in some specimens of both forms. This factor is very variable in *meridionalis* (from 0.035 to 0.156), and it is certain that if a larger number of specimens were measured these limits would be extended. There is no difference whatever to be found in the structure of the genitalia of the two forms, not even in the arrangement of the sensory setae of the parameres; the penis sheaths, which, other characters failing, usually give a clue to the identity of specimens belonging to very closely related species, as I have shown elsewhere,⁶ do not differ in any way in the two forms under discussion, nor from that of the following species; the shape of the tip and base is the same in all cases.

TABLE II.

Phlebotomus queenslandi meridionalis, subsp. n.

		Holo-type	Allo-type	Minimum		Maximum		Average*	
		♂	♀	♂	♀	♂	♀	♂	♀
Antennae Segt.	III	.128	.142	.121	.106	.128	.142	.125	.128
	IV	.085	.075	.078	.071	.085	.078	.080	.077
	XII-XVI	.284	.305	.227	.227	.280	.305	.253	.269
Palpi Segt.	II ...	.071	.071	.057	.064	.071	.071	.066	.067
	III ...	.107	.128	.107	.107	.107	.128	.107	.115
	IV ...	.135	.142	.121	.128	.135	.142	.128	.135
Wing :	Length	1.582	1.680	1.512	1.540	1.582	1.750	1.549	1.634
	width	.420	.476	.364	.420	.420	.490	.387	.451
	α	.210	.238	.182	.210	.210	.280	.196	.244
	β	.280	.322	.280	.280	.308	.350	.298	.316
	γ	.322	.322	.252	.280	.322	.322	.280	.304
	δ	.156	.098	.035	.084	.156	.156	.105	.119
Hind legs :	Femora	.630	.700	.588	.616	.630	.700	.601	.661
	Tibia	.812	.784	.756	.742	.812	.854	.779	.787
	Basitarsus	.378	.378	.322	.350	.378	.392	.345	.374
	Tarsi II-V	.560	.560	.476	.518	.560	.588	.506	.556
Total ...		2.380	2.422	2.142	2.226	2.380	2.534	2.231	2.378
Hypopygium :									
	Coxite	.241	—	.213	—	.241	—	.223	—
	Style	.099	—	.099	—	.099	—	.099	—
	Paramere	.177	—	.163	—	.177	—	.170	—
	Penis sheath	.107	—	.107	—	.107	—	.107	—
	Cerci	.199	—	.192	—	.199	—	.194	—
	Penis fil.	?	—	.298	—	.314	—	.308	—
	Pumpetia	.092	—	.085	—	.092	—	.088	—

*The average measurements are not those between the maxima and minima: they have been obtained from a large number of specimens.

This form is not so common as the following species, with which it is found. The only locality known so far is Yass, N.S.W., and the dates of capture range from December to the end of April. The type series consists of 12 males and 22 females in the collection of the Division of Economic Entomology.

Phlebotomus englishi, sp. n.

This species differs practically from the two preceding ones only by the characters given in the key to the species. The various measurements (Table III) are decidedly larger than in *P. queenslandi* but only very slightly larger than in *meridionalis*; the wing of the male is an exception, being intermediate in size between that of the two forms just mentioned. The male genitalia do not differ in any way from those of *P. queenslandi*, the spines of the style and the aedeagus being exactly as shown in fig. 2, *A* and *B*.

TABLE III.

Phlebotomus englishi, sp. n.

	Holo-type	Allo-type	Minimum		Maximum		Average*	
			♂	♀	♂	♀	♂	♀
Antennae Segt. III	.163	.142	.142	.134	.163	.156	.150	.143
IV	.092	.085	.085	.078	.092	.092	.087	.085
XII-XVI	.284	.298	.269	.298	.298	.305	.289	.299
Palpi Segt. II ...	.071	.081	.071	.071	.071	.085	.071	.078
III ...	.113	.113	.106	.113	.113	.134	.109	.121
IV ...	.134	.156	.134	.142	.142	.163	.138	.147
Wings : Length	1.540	1.704	1.470	1.704	1.540	1.834	1.458	1.796
Width	.304	.476	.364	.462	.392	.476	.373	.472
α	.168	.252	.168	.252	.238	.294	.216	.273
β	.308	.350	.238	.294	.308	.350	.264	.329
γ	.280	.336	.252	.280	.280	.336	.266	.318
δ	.042	.098	.042	.091	.140	.140	.091	.119
Hind legs : Femora	.602	.700	.588	.630	.616	.714	.602	.652
Tibia	.728	.868	.728	.770	.784	.924	.756	.854
Basitarsus	.364	.420	.336	.308	.378	.420	.360	.384
Tarsi	.532	.620	.532	.490	.560	.630	.539	.570
Total ...	2.226	2.608	2.184	2.198	2.338	2.688	2.257	2.460
Hypopygium :								
Coxite	.227	—	.213	—	.227	—	.225	—
Style	.099	—	.099	—	.094	—	.099	—
Paramere	.177	—	.177	—	.177	—	.177	—
Penis sheath	.085	—	.085	—	.085	—	.085	—
Cerci	.191	—	.184	—	.191	—	.186	—
Penis fil.	.319	—	.298	—	.319	—	.303	—
Pumpetia	.078	—	.078	—	.085	—	.083	—

*The average measurements are not those between the maxima and minima; they have been obtained from a large number of specimens.

A microscopical examination under high power will therefore always be necessary to separate this species from *P. meridionalis*, which is found in the same locality and at the same time of the year. Microphotographs of the buccal cavities and the pharynx of all these closely related species are given in Pl. 1, *a-h*.

The spermatheca illustrated in fig. 3, *B*, is that of a freshly killed female examined in water, but its well marked oval shape is not always so pronounced, but on the whole the spermatheca is more rounded and less elongated than in *P. queenslandi*. This difference is much more difficult to make out in preserved specimens mounted in balsam, as can be seen from fig. 3, *a* and *b*, because the basal part of the spermatheca usually collapses in the preparation.



AUSTRALIAN PHLEBOTOMUS.

- P. queenslandi*, ♀, a, buccal cavity; b, pharynx.
P. queenslandi meridionalis, ♀, c, bucco-pharyngeal armature.
P. brevifilis, d, buccal cavity and pharynx of ♂; e, of ♀.
P. englishi, f, pharynx of ♀; g, buccal cavity of ♂.
P. queenslandi, h, bucco-pharyngeal armature of ♂.

This species occurs abundantly in Yass; the series examined consists of more than one hundred specimens collected from December to April. The males are not quite so numerous as the females.



Fig. 2. A, style of *P. queenslandi*; B, aedeagus of *P. queenslandi*; C, coxite and style of *P. brevifilis*; D, aedeagus of *P. brevifilis*.

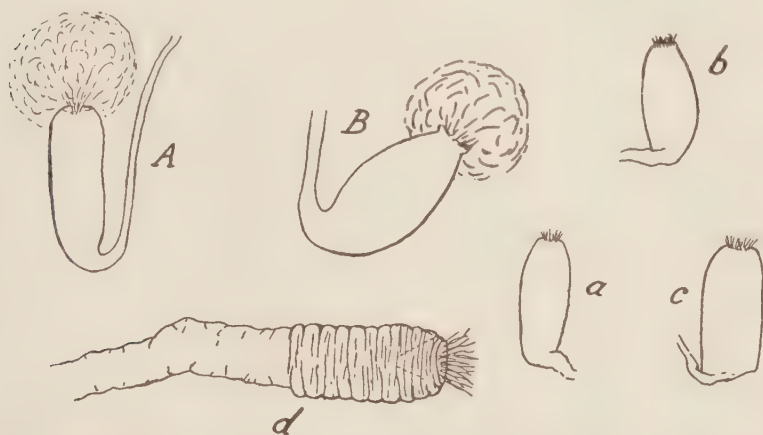


Fig. 3. Spermatheca of: A and a, *P. queenslandi meridionalis*; B and b, *P. englishi* (the capital letters indicate fresh material, the others preserved material); c, *P. queenslandi*; d, *P. brevifilis*.

Types in the collection of the Division of Economic Entomology, Canberra.

Phlebotomus brevifilis, sp. n.

This species of the erect-haired group is, so far as I am aware, quite unique by the absence of the penis sheaths and the very short penis filaments, which are only very little longer than the pumpetta (fig. 2, D). These filaments are thicker and therefore more rigid than usual; this may explain the absence of the sheaths. The three

spines (fig. 2, *B*) of the style are only found in *P. himalayensis*, Ann., in which they are all distal, and in *P. sergenti*, Parr., which also belongs to the erect-haired group. However, in *P. sergenti* there is a fourth appendage on the style; it is not a curved spine but a smaller straight sensory seta, as found in species of the *minutus* group; furthermore, *P. sergenti* is characterised by the presence of a hairy process at the base of the coxites.

The bucco-pharyngeal armatures in both sexes are typical of the *papatasi* group in the male, which has no buccal teeth (Plate I, *d*); but on the other hand the female has a few well developed ones (Plate I, *e*), which constitutes an exception in the group. The pharynx has a peculiar dark-coloured median area much more pronounced in the female; the triangular scales of the pharynx are numerous and almost as in *P. chinensis*; they are much less conspicuous in the male.

TABLE IV.

Phlebotomus brevifilis, sp. n.

	Holo-type	Allo-type	Minimum		Maximum		Average*	
	♂	♀	♂	♀	♂	♀	♂	♀
Antennae Segt. III	·198	·220	·198	·156	·205	·220	·201	·191
IV	·106	·106	·106	·085	·106	·106	·106	·100
XII-XVI	·384	·426	·384	·333	·384	·426	·384	·366
Palpi Segt. II ...	·106	·142	·099	·142	·106	·170	·102	·152
III ...	·134	·170	·134	·126	·134	·207	·134	·172
IV ...	·099	·120	·099	·099	·106	·127	·102	·114
Wings : Length	1·820	2·030	1·750	1·960	1·820	2·450	1·770	2·200
Width	·448	·546	·448	·532	·448	·644	·448	·583
α	·266	·378	·259	·378	·266	·588	·262	·487
β	·364	·350	·244	·364	·364	·448	·329	·366
γ	·332	·332	·332	·332	·350	·420	·341	·351
δ	·070	·168	·070	·168	·070	·332	·070	·323
Hind legs : Femora	·630	·826	·630	·658	·700	·882	·658	·800
Tibia	·911	1·092	·910	1·008	1·050	1·240	·957	1·116
Basitarsus	·490	·560	·490	·560	·528	·664	·507	·617
Tarsi	·658	·742	·644	·584	·700	·812	·667	·756
Total ...	2·689	3·220	2·674	2·810	2·978	3·598	2·789	3·289
Hypopygium :								
Coxite	·177	—	·177	—	·205	—	·191	—
Style	·106	—	·103	—	·106	—	·105	—
Paramere	·177	—	·177	—	·184	—	·180	—
Penis sheath	·043	—	·043	—	·043	—	·043	—
Cerci	·142	—	·142	—	·156	—	·149	—
Penis fil.	·156	—	·156	—	·213	—	·184	—
Pumpetia	·142	—	·142	—	·191	—	·166	—

*The average measurements are not those between the maxima and minima; they have been obtained from a large number of specimens.

The spermatheca (fig. 3, *d*) is of the type found in *P. papatasi*, but its rings are not well defined; they are rather irregular and run more or less into one another; the apical fibres come out of a funnel instead of being inserted on a knob.

According to Nitzulescu's classification of the genus and subdivision into subgenera⁷ this species should come in the subgenus *Sintonius*, as the buccal cavity is provided

with teeth and the spermatheca ringed, but its place is evidently in the subgenus *Phlebotomus*. This shows that Nitzulescu's classification does not rest on a sufficiently secure basis; from my knowledge of the PSYCHODIDAE I should say that his subgenera have at most the value of temporary groups.

The series of *P. brevifilis* studied consists of 4 males and 31 females from Canberra and Yass collected from November to March. Types in the collection of the Division of Economic Entomology, Canberra.

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SIREX NOCTILIO (HYM.) AND ITS PARASITE IN NEW ZEALAND.

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(PLATE II.)

Although on the whole our plantations of exotic conifers, now amounting to some 500,000 acres, have not yet suffered from widespread epidemics, there are certain exotic insects already well established in the country that must be considered as potentially dangerous. Attention is being given to the most important of these.

One species, though not a serious pest of healthy trees, has attracted considerable attention owing to its widespread establishment throughout the Dominion; this is the steel-blue horntail-borer or wood-wasp, *Sirex noctilio*, of Europe, which in this country attacks *Pinus radiata*, *P. ponderosa*, *P. laricio*, *P. muricata*, *P. austriaca*, *P. pinaster*, and *Larix europaea*, whilst on one occasion it was found attempting to oviposit in the native Miro (*Podocarpus ferrugineus*). Attacking suppressed, dying, and dead trees for the most part, this insect is nevertheless an important factor detrimental to forest protection since it may hasten the death of trees that could be utilised, as well as creating conditions favourable to the breeding of the European bark-beetle (*Hylastes ater*, Payk.), now well established in many regions. In this respect it is of importance to note that some large commercial concerns which have established extensive pine forests apparently intend to attempt the management of these upon a sustained yield basis with an extremely short rotation by a system of clear felling at the age of 12-16 years and subsequent replanting. Exotic conifers, maturing very rapidly in New Zealand, present ample pabulum for the larvae of *Sirex* at the above-mentioned ages, and the stumps of such trees attacked by that insect and infested with *Hylastes*, will, after clear felling, be centres from which *Hylastes* will spread and attack the fresh crop of seedlings, as has already been the case. Further, since exotic conifers have been planted somewhat indiscriminately all over the land, often without due consideration of site, some areas, having reached a fairly advanced state, appear to be weakening and becoming susceptible to *Sirex* attack. A further factor contributing to the development of *Sirex* is the lack of suitable plantation management. The basic difficulty is usually the fact that thinning, instead of yielding an intermediate return, such as might be expected under Old World conditions, is in most cases a definite additional capital charge, since small sizes of the timbers grown can only on rare occasions be profitably utilised. It is therefore not surprising that the average plantation owner avoids thinning, even when he realises that trees have to be farmed, as has any other crop, with the result that suppressed, broken, and dead trees comprising dense thickets are common.

Although suppression, breakage, and poor site are the most frequent causes inducing *Sirex* attack, the influence of fire and fungi cannot be overlooked. Very few plantations, outside those owned by the State and large commercial concerns, are adequately protected from fire, and it is no uncommon sight to see a considerable area of valuable trees irreparably damaged by accidental fires; this is particularly so when the plantations are situated along main highways or in the vicinity of settlements. Fire-killed trees, provided they are dried out, are not favourable for the breeding of *Sirex*, but in the case of light ground fires which cause the tree to wilt and to die gradually, the insect finds an excellent breeding ground. In the case of fungi, *Botryodiplodia pinea*, Cur., is found to attack several species of *Pinus*, and appears in some cases to

be linked to the presence of *Sirex*. It has been shown that the wood infested by *S. noctilio* larvae contains a fungus, possibly *Stereum sanguinolentum*, which may influence the insect's ability to exist in timber—a subject still under investigation.

There is no doubt in the minds of the authors that the prevalence of *S. noctilio* is due to the rapid expansion of afforestation, unfavourable site selection, fire, fungi, the lack of ordinary forest management, or its faulty application, and that the difference in forestry conditions between Europe and New Zealand gives a greater prominence to the insect in the latter country.

S. noctilio has been present in the Dominion for a considerable time ; as far back as 1900 the insect was found in the Wairarapa district of the North Island. For many years it was by no means a common species, but with the development and extension of areas under exotic conifers it has correspondingly increased and is now one of the commonest species met with amongst our insects of economic importance.

The wood-wasp reached New Zealand direct from England and Europe in shipments of lumber or in manufactured products ; in recent years we have records of the adults emerging from lumber in transit and on arrival, while there is the case of a piano from which emergences took place some time after the instrument had been sold in this country. It is of interest to note here that the giant wood-wasp (*S. gigas*) has reached New Zealand on rare occasions, while other species of the genus are sometimes met with in shipments in Californian redwood and in other timbers from the Pacific Coast of the United States.

Importation of *Rhyssa persuasoria*.

Owing to the abnormal abundance of *S. noctilio* in the plantations of exotic conifers steps were taken in 1927 to locate and introduce a parasite for its control. Adverse opinions were expressed upon the venture, since it was assumed that any attempt to introduce and establish a parasite of a wood-boring insect would fail. Why this should be so in the case of wood-borer parasites more than in the case of other insects, we failed to see ; and as the results to date have shown, the assumption was unfounded and demonstrates that one cannot definitely foretell the success or failure of any project connected with the biological control of insects.

In 1927, Sir Guy A. K. Marshall, Director of the Imperial Institute of Entomology, was communicated with for the purpose of securing supplies of *Rhyssa persuasoria*, known to parasitise *S. noctilio* in England, for shipment to New Zealand. The problem was placed in the hands of Dr. W. R. Thompson, Superintendent of the Farnham House Laboratory, and in December 1928 the first shipment of *Rhyssa* was received in New Zealand ; during the course of the researches in England another parasite, *Ibalia leucospoides*, was studied and some material sent to us, but nothing came of this second parasite.

As with the biological control of many other destructive insects, so in the case of *S. noctilio*, the opportunities for an introduced parasite becoming outstandingly effective are very favourable in New Zealand, since there are so many gaps in the insect parasite fauna of the country that can be judiciously filled without much fear of having their activities interfered with by related forms. Furthermore, in this particular instance there are no indigenous SIRICIDAE, and only one indigenous species of *Rhyssa*, *R. fractinervis*, which has for its host the larvae of the native so-called elephant beetle (*Rhynchodes ursus*), and which is confined to the natural forests of the country. It is just possible, however, that *R. fractinervis*, which has been found in *Pinus radiata* plantations, may extend its host range to *S. noctilio*, though the exotic conifers in which the latter breed are a totally different type of tree from the host trees of *R. ursus*. No hyperparasite of *R. fractinervis* is known, but if such occurs, there may be a chance of *R. persuasoria* being influenced by it.

The importation of *Rhyssa persuasoria* was carried out between December 1928 and April 1929, and again between March and August 1931 ; during these periods

nineteen consignments totalling 7,830 individuals were sent us from Farnham Royal. The insect was shipped in the larval stage under cool store conditions, and packed in gelatine capsules or corked glass tubes, a single larva to each receptacle. In some cases larvae had pupated and in others adults developed during the voyage. The shipments were, however, satisfactory, except where glass tubes were used, moulds doing considerable damage to the larvae under such conditions. The consignments were as follows :—Living individuals are marked (+) and dead or diseased (-).

Consignment	Received	Number	Condition on arrival			Per cent. alive
			Larvae	Pupae	Adults	
1st	8.xii.28	51	47(+) 4(-)	—	—	92·16
2nd	7.i.29	150	148(+) 2(-)	—	—	98·66
3rd	9.i.29	143	111(+) 31(-)	1(+)	—	78·32
4th	15.i.29	147	120(+) 15(-)	12(+)	—	89·75
5th	12.ii.29	100	45(+) 42(-)	9(+)	4(+)	58
6th	14.ii.29	147	57(+) 29(-)	5(-)	56(-)	38·77
7th	20.ii.29	228	78(+) 23(-)	16(+)	52(+) 59(-)	64·03
8th	7.iii.29	207	82(+) 56(-)	2(+)	67(-)	40·57
9th	13.iii.29	184	89(+) 26(-)	5(-)	13(+) 51(-)	55·43
10th	14.iv.29	96	37(+) 11(-)	7(-)	3(+) 38(-)	41·66
11th	6.iii.31	610	515(+) 43(-)	52(+)	—	92·95
12th	19.iii.31	690	568(+) 36(-)	86(+)	—	94·87
13th	24.iii.31	556	392(+) 31(-)	133(+)	—	94·42
14th	8.iv.31	248	135(+) 45(-)	68(+)	—	81·85
15th	13.iv.31	337	251(+) 35(-)	51(+)	—	74·48
16th	21.iv.31	1,200	966(+) 39(-)	195(+)	—	96·75
17th	14.iv.31	1,043	696(+) 100(-)	247(+)	—	90·41
18th	16.iv.31	1,242	813(+) 200(-)	229(+)	—	83·09
19th	6.viii.31	451	233(+) 112(-)	105(+)	1(+)	75·12

Some 160 parasite larvae of the 1928-29 consignments were sent in glass tubes, but in all other shipments gelatine capsules were used. The glass tubes were not a success owing to the accumulation of moisture and the development of mould upon the larvae. Many of these mould-affected larvae were saved by brushing with a very fine brush dipped in a saturated solution of boracic powder in cold water. This treatment was effective in removing the mould and allowed about 40 per cent. of the infected larvae to pupate, but the adults emerging from these were in poor condition. The capsules and tubes of the 1928-29 consignments were packed in cottonwool and those of 1931 in sawdust; both methods gave equally satisfactory results, though the sawdust apparently ensured more suitable conditions of moisture and temperature. In some cases sawdust was placed in the capsule with the insect, but no marked difference resulted.

Method of handling Parasites.

In the case of the parasites arriving in the 1928-29 season, upon arrival all were placed in suitable conditions in order to obtain emergences as quickly as possible. The parasites were unpacked, the dead and diseased insects removed and the healthy larvae or pupae placed in rearing boxes in a cool part of the laboratory. The first emergences were obtained in January 1929 and continued until May 1929. Further adults obtained from larvae which carried over the winter emerged from September 1929 to January 1930.

With regard to the consignments arriving during 1931 the pupae and prepupae of the first and part of the second consignment were allowed to develop under normal conditions of temperature, but owing to the lateness of the season the whole of the remaining consignments were placed in a cool store having a constant temperature of 41° F. for the purpose of retarding development till the spring. A number of pupae and prepupae from the second and third consignments were used for experimental purposes to observe the effect of low temperatures upon development. It was found that development could not be arrested in all cases by the application of a temperature of 41° F., it being noted that the retardation of development depended to some extent upon the amount of development which had already taken place. Thus it was found that some pupae even though packed in a metal container and placed directly upon a block of ice still continued their development and ultimately emerged in apparently good condition. The parasites arriving during 1931 were placed in the cool store still in their original containers, having been repacked after the usual examination had taken place upon arrival.

Although adults emerged when in cool store (41°F.), most of the larvae and pupae responded to low temperatures and were removed to ordinary temperatures in the spring (October). It was found that by far the greater number of adults were males (approximately two-thirds), while many of the females emerged with damaged ovipositors. Though these aborted females (in several cases no wings developed) mated readily enough with the males, they were unable to oviposit. Attempts were made to rectify the difficulty by treating the ovipositor in various ways but without success. One method consisted of placing the pupae in artificial burrows in pine wood to give the insect an opportunity of emerging under more or less natural conditions, this was of little use. However, if the females were given the freedom of a large insectary in which to fly immediately after emergence, it was found that in many cases the ovipositor assumed a normal state. Temperature had a direct influence upon the adults; at 40°F. they were sluggish, but became activated as the temperature rose; at 56°F. the insect will feed and at 60°F. become normally active, short flights being taken; copulation was noted at 64°F., while above that temperature maximum activity was reached. Conditions in New Zealand are thus favourable for acclimatising the insect. On the approach of winter any larvae and pupae remaining were held in cool store until the spring.

Liberation of Parasites.

Adults on emerging were allowed to mate in the insectary, after which some were liberated in *Sirex*-infested plantations, while others were retained for rearing purposes under insectary conditions. The females liberated in the plantations were observed to commence ovipositing almost immediately. The field liberations were as follows:—

Adults liberated from 1928—29 Consignments.

1929.

January	...	...	Marlborough	...	...	4 females, 8 males.
"	...	...	Wairau	...	...	4 females, 4 males.
February	...	...	"	...	...	6 females, 4 males.
"	...	...	Hanmer Springs	...	...	18 females, 12 males.
March	...	...	Palmerston North	...	...	2 females, 2 males.
April	Hanmer Springs	5 females, 5 males.
October	"	3 females, — males.
December	"	6 females, 5 males.

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Adults liberated from 1931 Consignments.

1931

September	Tasman	12 females, — males.
October	...	...	"	...	...	25 females, 5 males.
"	...	...	Wairakei	...	...	12 females, — males.
"	Moutere	9 females, — males.
December	Hanmer Springs	32 females, 7 males.
"	Moutere	15 females, — males.

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When only females were liberated these had been mated in the insectary. By the end of December 1931 emergence had ceased, and 365 larvae remained to overwinter. The mortality amongst these larvae was very high, but a few emergences were secured in the spring of 1932, and the following liberations were made:—

October	...	...	Ashburton	...	...	6 females, — males.
November	...	...	Braeburn	...	...	8 females, — males.
December	...	...	"	...	...	12 females, — males.

Insectary Rearings.

In order to keep a supply of *Rhyssa* in Nelson it was decided in 1931 to attempt the rearing of the parasite in the insectary. Logs infested by *S. noctilio* were brought from the field and stacked across trestles. Gravid females were placed with these, and oviposition was secured without any difficulty. The first New Zealand generation emerged in September 1932, a period of 10½ months, having completed the cycle of the earliest emergences. A second New Zealand generation was similarly produced in September and October of 1933. In no case was other than a perfect insect produced, and while the first generation was uniformly larger than the English stock from which it was bred, the second generation was larger still, a number of very fine females being produced. The largest of these had a body length of 1·3 inches and the ovipositor 1·7 inches. It would appear that this increase in size of *Rhyssa* is in keeping with that recorded by the host, *S. noctilio*, in New Zealand. In both generations males predominated, this being in keeping with the results obtained from imported stock.

Ibalia.

From the 21 imported *Ibalia* larvae no results were secured, though one male emerged. This is a more difficult insect than *Rhyssa* with which to deal.

Conclusion.

Judging from the development of *Rhyssa* in the insectary and from the fact that the insect readily oviposits under plantation conditions, there is every reason to expect that the parasite is now developing in the field, though recoveries from that source have not yet been seriously attempted. Field observers report the presence of the insect at several points of liberation, but this cannot be accepted with complete confidence.



RHYSSA PERSUASORIA, STAGES IN PROCESS OF OVIPOSITION.

ON THE BIOLOGY OF *DYSDERCUS HOWARDI*, BALLOU (HEM.).

By ELSIE I. MACGILL, M.Sc.,

University of Manchester.

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Introduction.

In May 1930 Mr. F. W. Urich of the Imperial College of Tropical Agriculture, Trinidad, brought to Manchester a number of cotton-stainers (*Dysdercus howardi*, Ballou). These were bred in the laboratory through several generations until November 1931, when the strain unfortunately died out without sufficient data for publication having been obtained. In July 1932, Mr. Urich was again in England and brought with him a further supply of the insects, which have been bred continuously since then. The material for this paper has been almost entirely obtained from the second strain of insects.

The stainers are kept in small glass museum jars, approximately 4 in. by 4 in. by 2½ in. ; each jar is lined with damp filter paper and contains a small wax drinking trough. The insects are fed on cotton seed with occasionally fresh cotton leaves and bolls. The jars are kept in an incubator at approximately 27° C. or on a hot plate at about the same average temperature, though this is less constant and is generally rather hotter during the day and colder at night than the incubator.

I should like to take this opportunity of thanking Mr. Urich for his great kindness in bringing the parent insects from Trinidad, and also Professor H. Graham Cannon and Dr. H. W. Miles for their helpful criticism of this paper.

Life-Cycle.

At approximately 27° C. the life-cycle of *Dysdercus howardi* occupies a little more than four weeks from the time the egg is laid till the first adult insects emerge. The following table gives the dates of the first eggs and the first female stainers obtained in fifteen generations, and from this it will be seen that there is very little variation in the length of the different generations.

The length of the life-cycle in a generation is counted from the day the first batch of eggs is laid, irrespective as to whether these hatch or not, until the day the first female stainer emerges ; usually, but not invariably, the first imagines of a generation are males, and these may emerge one or two days before the first females.

Ballou² gives the length of the life-cycle of *Dysdercus howardi* in Trinidad as approximately 47 days ; that is considerably longer than at 27° C., but this time is

based on the length of the life-cycle in only one or two individuals. In Northern Rhodesia the period of development from egg to adult is, according to the season, 25-47 days in *D. fasciatus*, Sign., and 35-48 days in *D. supersticiosus*, F.; in both species the male insects emerge before the females. Ulyett,⁶ in South Africa, gives the length of the life-cycle in *D. nigrofasciatus*, Stål, as from 47 days in warm weather to 82-83 days in the cold season.

Generation			Date of 1st eggs	Emergence of 1st female	No. of days
1	...	...	April 21	May 25	34
2	...	...	June 2	July 5	33
3	...	...	August 2	Sept. 3	32
4	...	...	Sept. 16	Oct. 17	31
5	...	...	Oct. 24	Nov. 24	31
6	...	...	Dec. 1	Jan. 3	33
7	...	...	Jan. 12	Feb. 13	32
8	...	...	Feb. 20	Mar. 24	32
9	...	...	April 1	May 6	35
10	...	...	May 15	June 20	36
11	...	...	June 29	July 31	32
12	...	...	Sept. 16	Oct. 14	28
13	...	...	Oct. 24	Nov. 24	31
14	...	...	Dec. 4	Jan. 3	30
15	...	...	Jan. 10	Feb. 12	33

Copulation.

Copulation does not, as a rule, take place as soon as the imagines emerge; at 27°C. the average time between emergence and copulation is 2.8 days, though there is considerable individual variation. A very few insects copulated as soon as they had completed the last moult, while others were ten days old before copulation took place.

In other species of *Dysdercus* the time between emergence and copulation is given as follows:—

<i>D. nigrofasciatus</i> , Stål	...	...	...	...	2-6 days
<i>D. sidae</i> , Montr.	...	...	...	...	3-4 days
<i>D. cingulatus</i> , Fabr.	...	...	86-99°F.		3-7 days
			77-87°F.		15 days
			50-77°F.		53-67 days

that is, in the first two species the length of time between the emergence of the adult insect and copulation agrees very well with the time of *D. howardi*, but at similar temperatures (77-87°F.) *D. howardi* has an average of 2.8 days before copulation, while *D. cingulatus* has 15 days.⁵

As in all species of *Dysdercus*, copulation in *D. howardi* is a prolonged process; the insects may remain together for several days and both the male and female continue to feed. Usually the insects re-copulate after each batch of eggs has been laid.

Oviposition.

At 27 C. oviposition begins, on an average 8 days after the last moult of the female stainer; the individual variation ranged from 5 to 22 days after the insect had become adult, though only a few insects varied more than one or two days from the average.

The eggs are about 1 mm. in length, oval and white in colour. They are laid in batches; the female digs out a hollow amongst the seed and after depositing a batch of eggs scrapes the seed over them to hide them. The number of eggs in a batch varies considerably, and one female may lay several batches at intervals of a few days.

The following table gives some typical examples of oviposition in *D. howardi* :—

Female emerged	1st eggs	Days after emergence	2nd eggs	Days between 1st and 2nd	3rd eggs	Days between 2nd and 3rd	4th eggs	Days between 3rd and 4th	Total eggs	Batches
April 13	106	8	121	5	126	4			353	3
„ 16	60	9	72	4	72	4			204	3
„ 23	47	8							47	1
May 1	94	7	105	3					199	2
„ 29	100	7	97	5	83	4			280	3
Oct. 17	101	7	114	4	102	4	94	5	411	4
„ 18	124	8							124	1
Jan. 6	86	7	110	4					196	2
„ 5	83	7	88	4	84	4	72	4	327	4
Feb. 20	84	8	105	4					189	2
May 20	86	9							86	1
July 31	83	5	109	4	102	3			294	3
Aug. 16	108	6	125	4					233	2
Nov. 28	87	6							87	1
Jan. 15	86	7	94	2	91	5	76	3	347	4

The largest number of eggs laid by a single female was 486 eggs in 5 batches, this being also the largest number of batches observed; the smallest number was 14 eggs in one batch. A large percentage (approximately 52 per cent.) of the female *Dysdercus howardi* reaching the adult state die without laying, even though they may live for a considerable time after the last moult; one female lived for 37 days without laying, and this proved to be the longest adult life of any of the female *Dysdercus*. The average number of eggs per female was 141.9 and the average number of batches laid was 2; in calculating these averages females that died without ovipositing were disregarded.

The following table gives the numbers of eggs obtained in 14 generations of *Dysdercus howardi* :—

Gen.	No. of females	Eggs	Average	No. laying females	Average
1	12	1,454	121.1	11	132.2
2	16	1,655	103.5	11	150.4
3	29	2,967	102.3	17	174.5
4	12	896	74.5	6	149
5	34	3,671	104	21	175
6	31	2,106	67.9	14	150
7	43	4,794	111.5	27	177.5
8	53	3,631	68.5	21	173
9	88	4,495	51.1	35	128.5
10	33	2,509	76	14	179
11	60	1,416	23.6	16	88.5
12	55	3,416	62.1	28	122
13	116	7,315	63.3	67	109.1
14	135	13,187	96.9	89	148.1

The lowest average of eggs in any generation is 23.16 eggs per female and the highest 121 eggs per female, or, only counting laying females, the lowest average was 88.5 and the highest 179 eggs per female.

Dysdercus howardi does not appear to lay so many eggs as some of the other cotton-stainers; *D. nigrofasciatus* may lay as many as 12 batches of eggs per female, and the average number of batches is eight. The maximum number of eggs obtained from one female in this species was 1,354 eggs in 12 batches, and the minimum number is given as 481 eggs in 5 batches. The largest number of eggs in one batch was 151 and the smallest number 36. In *D. sidae* the number of batches of eggs varies from 4 to 10 per female, and the maximum number of eggs laid by one female was 862 in 10 batches; the maximum number of eggs in a batch is given as 151 and the minimum 13. The number of eggs in one batch varies from 50 to 121. In *D. howardi* the largest batch contained 164 eggs and the smallest 5 eggs. The average number of eggs in one batch was 78.3.

The average number of eggs in each batch is as follows :—Average number of eggs laid in 1st batch, 79.1; 2nd batch, 82.2; 3rd batch, 73.9; 4th batch, 69.1; 5th batch, 66.6. That is, the 2nd batch of eggs laid by a female tends to be a little larger than the first, but after this the subsequent batches are a little smaller, though there is not a very great variation in the average size of the different batches.

There is an interval of approximately 8 days between the emergence of the adult female and the time when the first eggs are laid, the average length of time between the laying of the other batches of eggs being as follows :—Days between emergence and 1st eggs, 8; between 1st and 2nd eggs, 4.3; between 2nd and 3rd eggs, 4.5; between 3rd and 4th eggs, 4.5; between 4th and 5th eggs, 5.

Fertility of Eggs.

Approximately 38.4 per cent. of the eggs laid are infertile in spite of copulation having taken place. This percentage only includes eggs in which the whole batch showed no sign of development; in addition to these it is usual for some eggs in a batch of fertile eggs to fail to hatch. Ballard, working on *D. sidae*, also finds infertile eggs in batches of fertile ones; he states that there is no indication that the second batch of eggs laid by a female contains more infertile eggs than the first. *D. howardi* also shows no evidence that the second batch of eggs laid by a female contains more infertile eggs than the first batch, but the third and subsequent batches do tend to contain more infertile eggs than the first or second.

The percentage of infertile eggs (complete batches) in the five different batches that may be laid by one female is as follows:—1st batch, 37.9; 2nd, 34.7; 3rd, 40.4; 4th, 54.8; 5th, 67.8.

The average fertility of the first and second batches of eggs laid by one insect is higher than in the later batches. The second batch of eggs, as well as usually containing more eggs than the first batch, tends to be slightly more likely to hatch.

Mortality.

The number of adult insects obtained is approximately 16 per cent. of the 1st stage nymphs.

The following table gives the number of eggs hatched in 14 generations and the number of adult insects obtained in each case:—

Number	1st stage nymphs	Adults	Percentage of nymphs reaching adult stage
1	376	47	12.5
2	267	58	21.7
3	386	157	46.7
4	831	93	11.1
5	329	77	23.4
6	1,131	85	7.5
7	469	91	19.6
8	1,032	123	11.8
9	646	130	20.1
10	1,272	112	8.8
11	668	126	18.8
12	171	112	65.7
13	1,040	244	23.4
14	2,396	317	13.2

The minimum number of 1st stage nymphs reaching the adult stage in any generation is 7.5 per cent. and the maximum number is 65.7 per cent. The figure

16 per cent. given as the total number of adults obtained from the eggs hatched is probably unnaturally low, as, if the table is examined, it will be seen that when a particularly large number of eggs hatch the resulting percentage of imagines is usually very low; and this high death-rate may be partly due to the fact that the nymphs are overcrowded in the young stages. This is further supported by the fact that in one generation an abnormally small number of eggs hatched (171), but 65·7 of these nymphs became mature. The following figures probably give a more natural picture of the mortality in this species. 1st stage, 1,000; 2nd stage, 823; percentage 1st reaching 2nd stage, 82·3; 3rd stage, 595; percentage 1st reaching 3rd stage, 59·5; percentage 2nd reaching 3rd stage, 72; 4th stage, 507; percentage 1st reaching 4th stage, 50·7; percentage 3rd reaching 4th stage, 85; 5th stage, 426; percentage 1st reaching 5th stage, 42·6; percentage 4th reaching 5th stage, 84; adult, 269; percentage becoming adult, 26·9; percentage 5th becoming adult, 61. The 1,000 1st stage nymphs was made up of groups of nymphs taken from all the generations of *D. howardi*. These groups were watched carefully to find how many survived each of the moults. The batches of 1st stage nymphs were never very large, usually containing about 50 insects, as it was difficult to keep careful account of large numbers of nymphs at the same time; in this way overcrowding of the nymphs was avoided and the resulting percentage of adults (26·9 per cent.) is higher than the total percentage of adult insects. The death-rate is highest in the last (5th) nymphal stage, only 61 per cent. of the 5th stage nymphs becoming adult. Mortality is also high in the 2nd stage, only 72 per cent. of the 2nd stage nymphs reaching the 3rd stage; but there is very little variation in the death-rate for the other stages.

Sex Ratio.

The ratio of female *Dysdercus howardi* to male is 1 : 1·27; that is, the males are a little more numerous than the female insects. In the following table the ratio of female insects to male in 20 generations is given:—

Number	Females	Males	Ratio females to males
1	6	6	1 : 1
2	37	32	1 : 86
3	74	83	1 : 1·12
4	31	27	1 : 87
5	102	116	1 : 1·13
6	12	23	1 : 1·93
7	40	53	1 : 1·32
8	34	43	1 : 1·26
9	31	54	1 : 1·74
10	43	48	1 : 1·11
11	53	70	1 : 1·32
12	63	67	1 : 1·06
13	88	116	1 : 1·31
14	42	70	1 : 1·66
15	33	51	1 : 1·54
16	60	66	1 : 1·1
17	55	57	1 : 1·03
18	116	128	1 : 1·1
19	135	182	1 : 1·35
20	125	214	1 : 1·71

It will be seen that in every generation except three the male insects out-numbered the female. In the first generation only twelve insects survived, and these were equally divided between the sexes; in two other early generations (2 and 4) the female insects were slightly more numerous than the males. These three generations

all belonged to the first series, that is, the descendants of the first cotton-stainers brought from Trinidad; in the second series, generations 6 to 20, the male insects were always more numerous than the female, though in some generations there was very little difference in the numbers of the sexes. The greatest difference in number between male and female was in the first generation of the second series (6), only 35 insects survived but of these almost two-thirds were males.

Longevity of Female.

The average length of adult life in the female *Dysdercus howardi* at 27°C. is eleven days. Approximately 2 per cent. of the females die within the first twenty-four hours after the last moult and only a very few (approximately 0.8 per cent.) live for more than 28 days; 90 per cent. of the female insects live under 22 days and 30 per cent. do not survive the first week. The maximum length of adult life observed in any female insect was 37 days and the individual never oviposited. The average length of adult life in the male *Dysdercus howardi* appears to be slightly longer than in the female, as the first insects becoming mature in a generation are usually males and a few male stainers generally survive after all the females of a generation are dead. In *Dysdercus nigrofasciatus* the average length of life in the adult female is given as 58 days as against 66 days in the male; a female *Dysdercus sidae* is recorded as living for 70 days without laying.

Comparison with other Species.

In the following table *Dysdercus howardi* is compared with some of the other species of the genus *Dysdercus* :—

Species	Length of life-cycle	Average length of adult life		Days between emergence and copulation	Eggs		No. of batches per female	Max. eggs per female
		F.	M.		Largest batch	Smallest batch		
<i>D. cingulatus</i>				86–99°F. 3–7 77–87°F. 15 50–77°F. 53–67	121	50		
<i>D. fasciatus</i> ...	25–47 days				151	36		
<i>D. howardi</i> ...	Trin. 47 days 27°C. 32 days	11 days	11± days	2.8 (av.)	164	5	1–5	486
<i>D. nigro-fasciatus</i>	47–82 days	58 days	66 days	2–6			1–12	1,354
<i>D. sidae</i> ...				3–4	151	13	4–10	862
<i>D. supersticiosus</i>	35–48 days							

Summary.

1. At 27°C. the life-cycle of *Dysdercus howardi* occupies approximately 32 days.
2. Copulation (at 27°C.) takes place approximately 2.8 days after the last moult of the female insect.
3. At 27°C. oviposition begins about 8 days after the last moult of the female, and 5–6 days after mating.
4. The average number of eggs laid by one female is 141.9 and the average number of batches is two.

5. Mortality appears to be highest among the 5th stage nymphs.
6. The ratio of females to males is 1 : 1·27.
7. The average length of adult life in the female *Dysdercus howardi* is eleven days.
8. A table comparing *D. howardi* with other species of the genus *Dysdercus* is given.

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ON THE NAME OF THE "BLUE OAT MITE" OF AUSTRALIA.

By H. WOMERSLEY.

(Communication from the South Australian Museum.)

This mite was described by Froggatt as attacking oats in New South Wales in 1921 (Agric. Gaz. N.S.W. 3rd Jan. 1921) under the name of *Notophallus bicolor*, sp. n., but with a very inadequate description. In my paper of 1933 "On some Acarina from Australia and South Africa" (Trans. Roy. Soc. South Aust. **57**, pp. 108-112) I recorded it from the Cape Town area of South Africa, as well as from certain States of the Australian Commonwealth, giving a redescription and detailed figures. The generic name was changed to *Penthaleus*, as it had been shown that *Notophallus* of Canestrini 1886 was synonymous with Koch's *Penthaleus* of 1838. At that time, although so far as I was aware no recent redescription of any of the European species of *Penthaleus* had been published, I gave *P. bicolor* (Frog.) as doubtfully synonymous with *P. major* (Dugès 1834), a species considered by European workers as the same as *P. haematopus*, Koch 1835, and *P. insulanus*, Thorell, 1872.

Some time ago Dr. Marc André, of the Paris Museum, kindly sent me a copy of his paper "Note sur un Acarien (*Penthaleus major*, Dugès) nuisible aux plantes potagères" (Bull. Mus. Paris 1932), in which he gave a very careful redescription of Dugès' species and added *P. erythropus*, Koch 1835, to the list of synonyms.

A careful comparison of my Australian material with André's figures and description seemed to confirm my earlier impression that I had the same species before me. I therefore requested Dr. André to send me some European specimens and in return I sent some Australian material to him. As a result of this cross examination we have both come to the conclusion that no differences are to be found between *P. bicolor* (Frog.) and the European *P. major* (Dugès).

The synonymy of the species therefore stands as follows:—

***Penthaleus major* (Dugès 1834).**

- = *Tetranychus major*, Dugès 1834.
- = *Penthaleus haematopus*, Koch 1835.
- = " *erythropus*, Koch 1835.
- = " *insulanus*, Thorell 1872.
- = *Notophallus bicolor*, Frog. 1921.
- = *Penthaleus bicolor*, Wom. 1933.

HISTOLOGICAL RESEARCHES INTO THE ACTION OF INSECTICIDES ON THE INTESTINAL TUBE OF INSECTS.

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(Plates III-VI.)

The object of the present work is to study the histological picture of the intestinal tube of insects when subjected to the action of insecticides, in order to discover the mechanism of the action of poisons on insects.

Experiments have been made successively, in order of time, with caterpillars of the Small Tortoiseshell Butterfly (*Aglais urticae*), larvae of the Migratory Locust (*Locusta migratoria*), and caterpillars of the Gypsy Moth (*Porthetria dispar*) and those of the Cabbage Butterfly (*Pieris brassicae*). The poisons used were sodium fluoride (NaF), sodium silicofluoride (Na_2SiF_6), arsenites of sodium and calcium, and Paris green (copper aceto-arsenite), in the form of solutions or powder, spread on leaves which were given as food to the insects under observation.*

The dissection of insects poisoned was performed at varying intervals after the beginning of poisoning, from half an hour to 24 hours and upwards; usually insects have been dissected when still alive, or immediately after death. Extracted intestines were fixed by means of 10% formalin (aqueous solution of formaldehyde) or Branca's mixture and then embedded in paraffin. Sections were mostly made in a longitudinal direction because a uniform preparation of the intestines would facilitate a comparison of the varying effects that might be produced by the different poisons.

For staining, the preparations used were Ehrlich's haematoxylin with eosin, Heidenhain's haematoxylin, and Mayer's alum-carmin with Mallory's mixture. The last stain gives especially good results and clearly differentiates all histological elements in the intestinal tube of insects.

The examination of the histological picture of the intestine of poisoned insects was always preceded by a thorough study of the normal intestine of the same insects. In all the cases in which it was possible to detect any deleterious action of the poison on the intestine of an insect, it was only the mid-intestine that suffered from this action. We do not usually observe any histological changes in the fore and hind parts of the intestine, even if the insect is killed by the poison, because the chitinous cuticle covering these parts protects them from the action of the poison. Therefore, the statements in this paper will refer only to the region of the mid-intestine.

To my friend, Prof. N. J. Kusnetzov, of the Academy of Sciences, Leningrad, I here offer my sincerest thanks for his assistance in my work.

Experiments with *Aglais urticae*, L.

These experiments were made with caterpillars of the 5th instar, and the poisons used were sodium fluoride, sodium silicofluoride, sodium arsenite, and calcium arsenite. The autopsy was performed 17 or 18 hours after poisoning, in some instances after the death of insects and in others on still living insects showing more or less clear symptoms of poisoning.

*These experiments in poisoning insects were conducted by the following scientific workers of the Institute for Plant Protection: B. Dadonov, Mme. E. Skriabin, and Mme. A. Voskresensky, whose valuable assistance is here gratefully acknowledged by the author.

The histological structure of the mid-intestine of the caterpillars of this butterfly is simple and uniform through its whole extent. The epithelium is made up of columnar cells with a striated marginal fringe (the "striated hem") on the free surface. These cells emit a fairly strong secretion (fig. 1). As soon as they become free from secretion the columnar cells assume the aspect and form of calyciform cells, whose number visibly increases toward the posterior end of the intestine. The epithelium lies on a thin connective membrane, which we stain blue by means of Mallory's mixture, like the collagenous elements of connective tissue. Under this membrane is situated a muscular coat consisting of two layers, one of which is interior and annular, and the other exterior, longitudinal, and made up of striated muscle-fibres, which, however, do not form any compact layers.

The action of poisonous substances entering the intestinal tube with the food especially affects the epithelium. The connective membrane in all cases remains intact. The muscular coat seems to change very little, too, save an energetic contraction and separation of its elements.

In caterpillars dissected *post mortem* the changes produced by the poison in the epithelium are very profound and present characteristic features. The anterior part of the mid-intestine, immediately following the oesophagus, is entirely deprived of epithelium. The whole wall of the intestinal tube is represented merely by a connective membrane and muscle elements overlying it on the outside. No traces of epithelium are to be found, not even in the form of disintegration elements or detritus, in the cavity of the intestine; the epithelium perishes completely (fig. 2).

Somewhat farther in the rear, close by the connective membrane or lying loose in the cavity of the intestine, is seen a finely-granulated mass, formed of the disintegrated elements of epithelial cells but showing no traces of cellular structure (fig. 3). Still farther in the rear we find separate epithelial cells or small accumulations of such cells with distinct nuclei, which lie on the connective membrane or in the cavity of the intestine between this membrane and the peritrophic membrane (fig. 4). The number of such cells that have escaped destruction increases more and more towards the posterior end of the intestine, and at a certain distance from the anterior end the epithelium is found to be intact and normal (fig. 5). The part of the intestine affected by the poison differs even macroscopically from the remainder; even after being embedded in paraffin, it looks black, as if it were charred. The length of the damaged portion varies in different cases from one-half to two-thirds of the whole intestine.

Caterpillars which before dissection have shown violent symptoms of poisoning present, in some cases, a similar picture of destruction of the epithelium in the anterior part of the mid-intestine, whereas it remains intact in the posterior part of the intestine. In other caterpillars the epithelium is intact throughout the entire extent of the mid-intestine, but in its anterior part shows strong vacuolisation. In the vacuoles we may observe agglomerations of a brown substance of varying size and form. The number and size of the vacuoles increase posteriorly, and the epithelial cells secrete energetically. Small particles seem to be detached from the inner ends of these cells, which is probably the initial stage of disintegration of the epithelium.

The same picture of vacuolisation of the intestinal epithelium with agglomerations of granules of a brown substance is presented by specimens which prior to dissection have shown but slight symptoms of poisoning, but no disintegration or destruction of the intestinal epithelium is to be found here; the epithelium preserves its integrity and continuity throughout the entire extent of the intestine (fig. 6).

Experiments with *Locusta migratoria*, L.

The experiments with the migratory locust were divided into two series. The material for the first series had been collected in the Kizlar district of Daghestan,

Poisoning was performed by means of sodium fluoride, sodium silicofluoride and calcium arsenite, which were added, in the form of solutions, to the food of the insects. In order to obtain an indubitable action of the poison, strong concentrations (from 1 per cent. to 5 per cent.) were employed. The dissection of the insects took place at various intervals of time after feeding (from 10 minutes to 6 hours) or immediately after death, which occurred at very unequal intervals, from 3 to 48 hours after the ingestion of the poison.

The second series of experiments was conducted on larvae of *Locusta migratoria*, bred in the summer of 1932 and 1933 in our laboratory in Leningrad. The poisons used were Paris green, sodium silicofluoride and sodium arsenite, in comparatively weak doses—from 0.01 to 0.4 milligrams per gram of live weight of insects. The dissections were made at intervals varying from one hour to many days after the beginning of poisoning, usually on still living insects, but also partly *post mortem*.

The histological pictures of the intestinal tube in the first and second series of these experiments present considerable divergences, and these are therefore described separately.

Normal Structure of the Intestinal Tube.

The histology of the intestinal tube of *Locusta migratoria* is described in an article by Nenjukov & Parfentjev, "Digestive Process and Structure of Intestine in the Migratory Locust."* My observations, on the whole, agree with, and in certain points supplement, those made by these authors.

The intestinal tube of the locust, from an anatomical point of view, is subdivided into the fore, mid, and hind parts, the mid-intestine being the shortest. The dividing-line between the fore and mid parts coincides with the opening of the coecal tubes, and that between the mid and hind parts with the opening of the Malpighian tubes. In the fore intestine we may distinguish two parts: the narrow pharynx and the voluminous gizzard. In the hind intestine we distinguish three parts: the first is large in diameter and communicates directly with the cavity of the mid-intestine; the second, more slender, with a well-developed muscular layer (sphincter); the third is the rectum, with its rectal glands. The fore intestine is lined inside with a thick layer of chitin, in which, after having stained it by Mallory's method, may be distinguished two layers—one, lying deeper, thick and taking a blue colour, and the other, superficial, thin and yellow.

Under the chitin lies one row of medium-sized epithelial cells with large nuclei and granular inclusions in the protoplasm. On the outside of the epithelium there is a well-developed muscular coat consisting of two layers, of which the interior one is longitudinal and the exterior one annular. The muscular fibres are striated, as they are also in the posterior parts of the intestinal tube. The epithelium of the mid-intestine consists of high columnar cells with a marginal fringe on the free surface. The cells are arranged fan-wise round the projections of a connective base, and their nuclei lie at different levels, upon one another, making the epithelium look stratified (fig. 7). The intestinal epithelium of the locust is highly capable of regeneration. Numerous mitotic figures at different stages are usually met with in all preparations of the intestinal tube.

Under the epithelium lies the connective membrane, consisting of fibres and cells and forming papillae which deeply penetrate into the epithelium, in the same manner as the tunica propria of the mucous membrane in mammals. When stained by Mallory's method, this connective membrane is particularly conspicuous owing to its blue colour (fig. 7). Still more instructive are the preparations in which the intestinal epithelium has been destroyed by the action of the poison, and the subjacent connective membrane laid bare (fig. 11). Besides fibres and cells, there are in the

* Plant Protection (formerly La Défense des Plantes), 6, nos. 1 & 2, 1929.

connective membrane fine ramifications of the tracheae, which pass through the muscular coat lying on the outside. How these tracheae terminate, and whether they penetrate into the thick of the epithelium, as may be observed in the rectal glands, I have not yet been able to ascertain.

The muscular coat of the mid-intestine consists of three layers: an inner longitudinal, a middle annular, and an outer longitudinal layer. The inner layer is very thin and is often composed of small groups of fibres divided from one another by interstices, and in transverse sections it can easily be overlooked. It is seen more distinctly in longitudinal sections through the intestine, when the muscular fibres come into the field of vision over a great extent. The middle layer of the muscular coat is the most developed and is composed of muscular fibres compactly lying together. The outer layer consists of isolated muscular fascicles.

Comparing structures of the intestine in larvae of different instars it is necessary to direct attention to the fact that these structures gradually become more complicated and pass from a comparatively simple form in young larvae to a more developed one in imagines.

The epithelium of the mid-intestine in larvae of the first instar is columnar, uniserial, with a marginal fringe. The connective membrane is very feebly developed and papillae are still lacking. The inner longitudinal muscular layer is not differentiated. The muscular coat is composed of two layers; an inner annular and an outer longitudinal layer. The muscular layers are very thin (fig. 8).

In larvae of the 2nd instar the epithelium of the intestine is considerably higher. The connective membrane and the muscular coat are still thin, but the inner longitudinal muscular layer begins already to be differentiated (fig. 9).

Larvae of the third instar already show a greater approximation to the imago with respect to the structure of the intestinal tube. The epithelium becomes still thicker, though conserving its distinct uniserial structure. The papillae of the connective membrane begin to develop; all the layers of the muscular coat become thicker (fig. 10).

In larvae of the fourth and fifth instars we see all the features characterising the mid-intestine of the imago.

The hind part of the intestinal tube of the locust, as well as the fore part, is lined within with chitin over all its extent, beginning at the openings of the Malpighian tubes. The epithelial cells are cubical in the fore part of the intestine, but gradually become higher in the region of the sphincter and especially in the rectal glands. The connective reticular membrane of the rectal glands is well developed and plentifully supplied with ramifications of numerous tracheal branches. These slender branches run from thence towards the epithelium of the rectal glands, penetrate into the interstices of the epithelial cells, ramify, and probably terminate in some special cells.

Especially instructive are those preparations in which the free ends of the cells with their chitinous cuticle have been torn from the basal ends, while through the cavity thus formed pass, without being broken, slender tracheal branches.

The muscular coat of the hind intestine consists of two layers: an inner annular and an outer longitudinal layer.

Appearance of the intestinal tube after poisoning.

As mentioned above, poisoning in the first series of experiments was effected by solutions of sodium fluoride, sodium silicofluoride and calcium arsenite, in strong concentrations. The histological picture of the intestinal tube of all poisoned insects is characterised by identical features and does not give by itself any indications as to what insecticide has been used for poisoning. The epithelium may be destroyed over a greater or lesser extent, and the connective membrane, with its papillae, which

lies under the epithelium, is then denuded, changing the general view of the intestinal wall so that it is hardly recognisable at first sight (fig. 11).

It is only the period of time during which the action of a poison has lasted that is of material importance, and the longer the period between the dissection and the administration of the poison, the greater is the area of epithelium destroyed. It begins usually at the anterior end of the mid-intestine and gradually spreads to the rear, invading, after a prolonged action of the poison (20 hours and upwards), the whole mid-intestine. Such destruction of the epithelium may be preceded either by necrosis of the cells under the influence of the poison or by a transformation of the epithelium as a tissue. A careful study of microscopic preparations taken at different intervals after poisoning has led me to the conclusion that the latter phenomenon is just what occurs in this case.

Owing, probably, to a change in osmotic conditions the epithelium begins to exfoliate from the subjacent connective membrane in large sheets but retains, at least in the beginning, its typical morphological character. A picture of such exfoliation is given in fig. 12, which represents the anterior part of the mid-intestine after poisoning by means of 3 per cent. solution of sodium silicofluoride. Fig. 13 shows a similar exfoliation of the epithelium at the posterior end of the intestine 12 hours after poisoning by means of 3 per cent. solutions of sodium fluoride. The whole anterior part of the intestine in this preparation is deprived of its epithelium and presents a picture quite like that of fig. 11. In the contiguous area there is a narrow interstice between the epithelium and the connective membrane, and still farther to the rear the epithelium keeps its typical appearance. There is going on, so to speak, a tearing of the epithelium from the underlying layer, and the epithelium being disconnected undergoes disintegration.

That the epithelium, at the moment of its detachment, still retains its morphological character and physiological activity, seems to me to be proved convincingly enough by the presence of mitotic figures in some undestroyed portions of the epithelium, on the very brink of destruction as it were, or even in epithelial cells already exfoliated. Such portions of undestroyed epithelium may be seen, in some preparations, just at the beginning of the mid-intestine, in deep folds with openings of diverticula, which the poisoned food, to all appearances, could not reach. In other preparations, these undestroyed portions are to be found only in the rear end of the intestine, where the action of the poison, owing to various causes, could not yet become manifest.

Fig. 14 shows the anterior part of the intestine of the locust 24 hours after poisoning with 3 per cent. sodium silicofluoride. On the left side of the figure the intestinal wall is deprived of epithelium; on the right is seen a remaining portion of undestroyed epithelium with two mitotic figures at the stage of loose spirems changing into monasters.

Fig. 15 shows a portion of the posterior part of the mid-intestine 5 hours after poisoning with 5 per cent. sodium silicofluoride. On the right, the limit reached by the exfoliation of the epithelium; on the left, within undestroyed epithelium is seen a monaster.

I do not deny the fact that, as long as the epithelium retains its connection with the underlying layer, though quite near destruction, mitoses in it may seem natural and do not wholly eliminate the supposition of a possible necrosis of cells before the moment of their separation. But the presence of mitoses in exfoliated epithelial cells, as shown in fig. 16 representing a preparation of the mid-intestine 5 hours after poisoning with 3 per cent. sodium silicofluoride, must be considered as an undeniable proof that at the moment of their exfoliation epithelial cells are still living and not undergoing necrosis. It follows as a matter of course that, having lost connection with its nourishing base and falling free into the cavity of the intestine, the epithelium undergoes disintegration and destruction.

In the second series of tests three poisons were used: Paris green, sodium arsenite, and sodium silicofluoride, in comparatively small doses.

The histological picture of the intestinal tube of insects poisoned with Paris green in different doses (0.04 to 0.08 mgr.) and at different intervals after poisoning (6 hours to 41 hours) does not present any distinct changes. In all cases the epithelium of the mid-intestine retains its normal character and throughout its extent there are to be seen numerous mitoses at different stages (fig. 17).

Sodium arsenite and sodium silicofluoride give a more complicated picture. In some insects, after poisoning with sodium arsenite, it is also impossible to find any changes in the intestinal epithelium, whether the dissection is performed on a living insect or after its death (fig. 18). The more numerous mitotic figures alone indicate an intensification of regenerative processes.

In other insects the epithelium is destroyed over a greater or less extent of the mid-intestine. It exfoliates either in small particles or in large sheets, laying bare the underlying connective membrane (fig. 19). The nuclei of the cells of this membrane, which are usually stained an intense dark colour, gradually fade off and are but faintly seen among the surrounding connective elements (fig. 20).

In order to study the picture of the gradual change of the epithelium, the intestinal tubes were fixed whole without any previous incision. Nevertheless, in the cavity of the intestine there are seen but insignificant remains of disintegrated epithelium in the form of separate cells with picnotic nuclei, or in that of detritus. Obviously, the greater part of the exfoliated epithelium has been evacuated with the remains of the food.

It is possible to establish the following relation between the quantity of poison swallowed by the insect and the period of time which has elapsed between the beginning of poisoning and the dissection of the insect. The less the dose of poison the longer the time necessary for the poison to produce its effect on the intestinal tube of the insect, and *vice versa*. With doses of one to some hundredths of a milligram (0.01, 0.02, 0.06, 0.07, 0.08 and 0.09 mgr.) the exfoliation of the epithelium takes place after 36 hours, 48 hours, and upwards. But if examined after 1 to 24 hours, with the same doses of poison, the intestines show no histological changes in their structure, even if the death of the insect happens before the moment of dissection.

On the contrary, with doses of one-tenth of a milligram and upwards (0.10, 0.11, 0.13, 0.14, 0.22 mgr.) the time necessary for the poison to produce its effect on the epithelium decreases proportionally (from 3 or 4 hours to 20 hours).

The data which I obtained in 1932, when studying the haemolymph of the same specimens whose intestinal tubes are described above, fully agree with what has been stated concerning the conditions of the intestinal tube in locusts poisoned with sodium arsenite.

Comparing the records which give the histological picture of the intestinal tube and the haemolymph of the same insects, we find that insects with uninjured intestinal tubes give also a normal picture of the haemolymph.

Among the blood corpuscles of some of these insects were found minute cellular forms (from 4 to 9 microns) and a varying number of mitoses, which indicates that regenerative processes begin in the haemolymph as well as in the intestinal epithelium. On the other hand, in insects with the epithelium of the intestinal wall wholly or partly destroyed, disintegration or intensified karyokinetic division occurs as a reaction and means of defence against the toxic action of the poison.

Comparing the histological picture of the mid-intestine of the locust after poisoning with sodium silicofluoride with that when sodium arsenite has been used, we must point out the greater resistance of the epithelium to the action of sodium silicofluoride.

With doses of 0.05 to 0.35 or 0.4 mgr. the histological structure of the mid-intestine in most cases presents no changes in 2 hours to 6 days afterwards, either in living insects or after death, which may take place $3\frac{1}{2}$ hours, $8\frac{1}{2}$ hours, 18 hours, 20 hours and 32 hours after poisoning. In comparatively rare cases some changes are observed which are somewhat different from those resulting from poisoning with sodium arsenite.

The epithelium of the mid-intestine presents features of degeneration, fusing into one uninterrupted mass, and boundary-lines between the cells disappear. The nuclear chromatin gathers into large irregular lumps, giving the nucleus a rough granular structure (fig. 21). Further, the whole chromatin forms a continuous compact mass, intensely coloured, subsequently breaking up into separate lumps of varied sizes. The structure of the nucleus becomes obliterated (fig. 22) and finally disintegration of the epithelium sets in, with denudation of the underlying connective membrane, as occurs in the case of poisoning with sodium arsenite (fig. 23).

The picture of the haemolymph and the state of the intestinal tube in this case present the same correspondence. As in the case of poisoning with sodium arsenite described above, the condition of the haemolymph is normal in insects with a normal mid-intestine. If changes appear in the epithelium of the intestine, we may then find disintegration of blood-corpuscles in the haemolymph or their intensified division and formation of minute cells.*

Experiments with *Porthetria dispar*, L.

Experiments were made with caterpillars of the 5th instar. The poison used was sodium silicofluoride, in some cases with an admixture of nicotine, bismuth, or sodium sulphate. Caterpillars were dissected at intervals of 1 hour to 7 days after the beginning of poisoning.

The histological structure of the mid-intestine in the Gypsy Moth, upon the whole, bears a great resemblance to that in the Tortoiseshell Butterfly and in the Cabbage Butterfly. The epithelium consists of high columnar cells in their typical uniserial arrangement, with a marginal fringe. Their protoplasm contains a varying quantity of oxyphil granules of different sizes. Among these columnar cells there is a certain number of cells similar to the calycitorm cells of mammals. The chromatin of the nucleus is in the form of small granules and lumps lying close to one another. There is usually one large-sized oxyphil nucleolus. In no preparation have I seen any dividing nuclei (fig. 24). The muscular coat is feebly developed and consists of two layers: an inner annular and an outer longitudinal layer. (In fig. 24 as well as in the following ones, the muscular coat is not shown.)

Although the intestines of more than 50 caterpillars were examined, I did not succeed in discovering any histological changes produced by poisoning. In all cases the epithelium remained intact through the whole extent of the intestine. Varying numbers of granules were found in the protoplasm of the cells; the number of calycitorm cells sometimes increased and sometimes decreased; the lumps of chromatin were now more loose and now more compact; but all these changes are within the limits of normal physiological conditions, and there is no reason whatever for considering them as results of a toxic action of the poison. Fig. 25 represents the anterior part of the mid-intestine 3 hours after poisoning with sodium silicofluoride.

*The above-mentioned histological data for locusts seem to me to be insufficient for a comparative evaluation of the toxic properties of sodium arsenite and sodium silicofluoride. According to the latest toxicological observations, the limit of lethal zones with respect to locusts is represented for sodium arsenites by doses of 0.029 mgr. per 1 gr. of live weight of insect, and for sodium silicofluoride by 0.34 mgr. The doses used in the above-described experiments are therefore not exactly commensurate with one another, and the histological pictures may present discrepancies and not correspond wholly with one another. Additional experiments and tests with new materials are necessary for the subject in question to be wholly elucidated.

Experiments with *Pieris brassicae*, L.

What has been stated concerning the Gypsy Moth is, to a great extent, applicable to the Cabbage Butterfly.

My experiments with this species did not bring me to conclusive results. The epithelium of poisoned larvae remains intact through its whole extent and does not present any essential histological changes. Caterpillars were poisoned with sodium arsenite (doses of 0.0125 to 0.1552 mgr.) and sodium silicofluoride (doses of 0.1415 to 0.729). The intestine was subjected to examination within 2 to 31 hours after the beginning of poisoning. The histological structure of the intestine of the larvae of the Cabbage Butterfly is similar to that of the Gypsy Moth. There is the same columnar uniseriate epithelium with a marginal fringe, and among these cells are found cells of the calyciform type. The chromatin of the nucleus is composed of finer granules, and the nucleolus is smaller. The protoplasm does not contain any oxyphil granules (fig. 26). As in the Gypsy Moth, there is no division of nuclei.

On comparing microscopic preparations of larvae poisoned with sodium arsenite and with sodium silicofluoride, certain differences were observed. When sodium silicofluoride is used the nuclei of the cells have a more compact structure and are stained a deeper colour than in the case of poisoning with sodium arsenite (fig. 27). In the latter case the intestinal epithelium has a greater resemblance to the normal histological picture (fig. 28).

This agrees to some extent with the statements above relating to the different effects of sodium arsenite and sodium silicofluoride on the intestinal tube of the locust, but additional investigations are necessary to clear up the problem definitely.

Conclusions.

In consequence of the facts stated above I have arrived at the following conclusions :—

(1) The final effect of the usually employed insecticides shows itself in the disintegration and destruction of the epithelium of the mid-intestine.

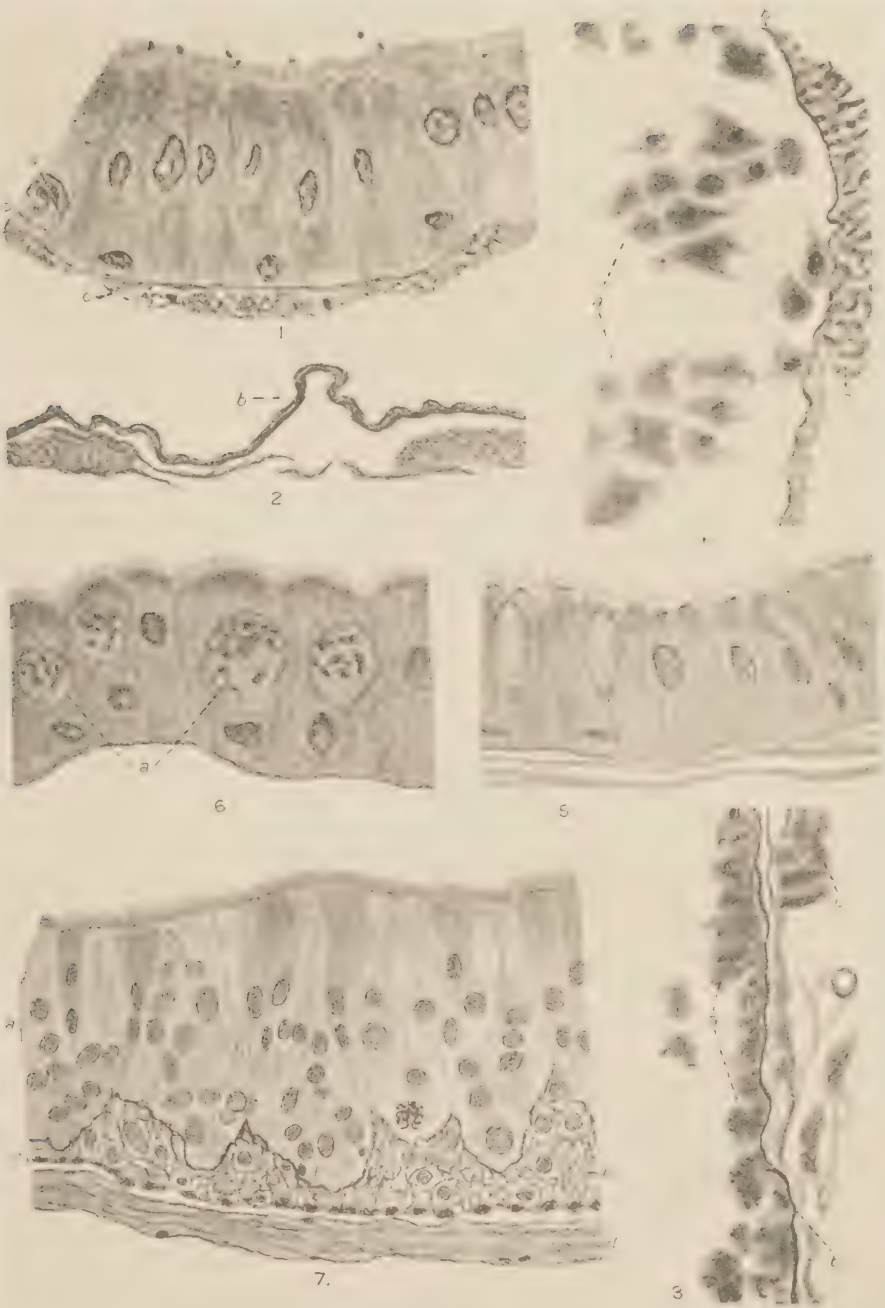
(2) This destruction is preceded by the exfoliation of the epithelium from the subjacent connective membrane.

(3) The histological picture of the intestinal epithelium at the first moment of the action of the poison shows certain peculiar features if compounds of fluorine are used.

(4) The histological picture of the intestinal tube of the poisoned insect corresponds with the picture of the haemolymph of the same insect.

EXPLANATION OF PLATE III.

- Fig. 1. Normal mid-intestine of small Tortoise-shell Butterfly (*Aglais urticae*), longitudinal section: *a*, epithelium with marginal fringe on free surface; *b*, connective membrane; *c*, inner annular layer of muscular coat.
- „ 2. Mid-intestine of caterpillar of small Tortoise-shell Butterfly poisoned with calcium arsenite, longitudinal section: *a*, anterior part, deprived of epithelium; *b*, connective membrane; *c*, inner annular layer of muscular coat.
- „ 3. Mid-intestine of the same caterpillar (see fig. 2), farther to the rear, with disintegrated epithelium in the form of detritus (*a*); *b*, connective membrane; *c*, inner annular layer of muscular coat.
- „ 4. Mid-intestine of the same caterpillar, still farther to the rear, with exfoliated epithelial cells (*a*); *b*, connective membrane; *c*, inner annular layer of muscular coat.
- „ 5. Mid-intestine of the same caterpillar, posterior part, with undestroyed epithelium. Light-coloured cells are of the calyciform type.
- „ 6. Mid-intestine of caterpillar of Tortoise-shell Butterfly, showing weak symptoms of poisoning by means of calcium arsenite. Epithelium cells contain large-sized vacuoles with inclusions of a brown substance (*a*).
- „ 7. Normal mid-intestine of adult locust (*Locusta migratoria*), cross-section: *a*, epithelium, with marginal fringe on free surface; *b*, connective membrane of cellular character; *c*, inner longitudinal muscular layer; *d*, middle annular muscular layer; the outer longitudinal layer is not shown.

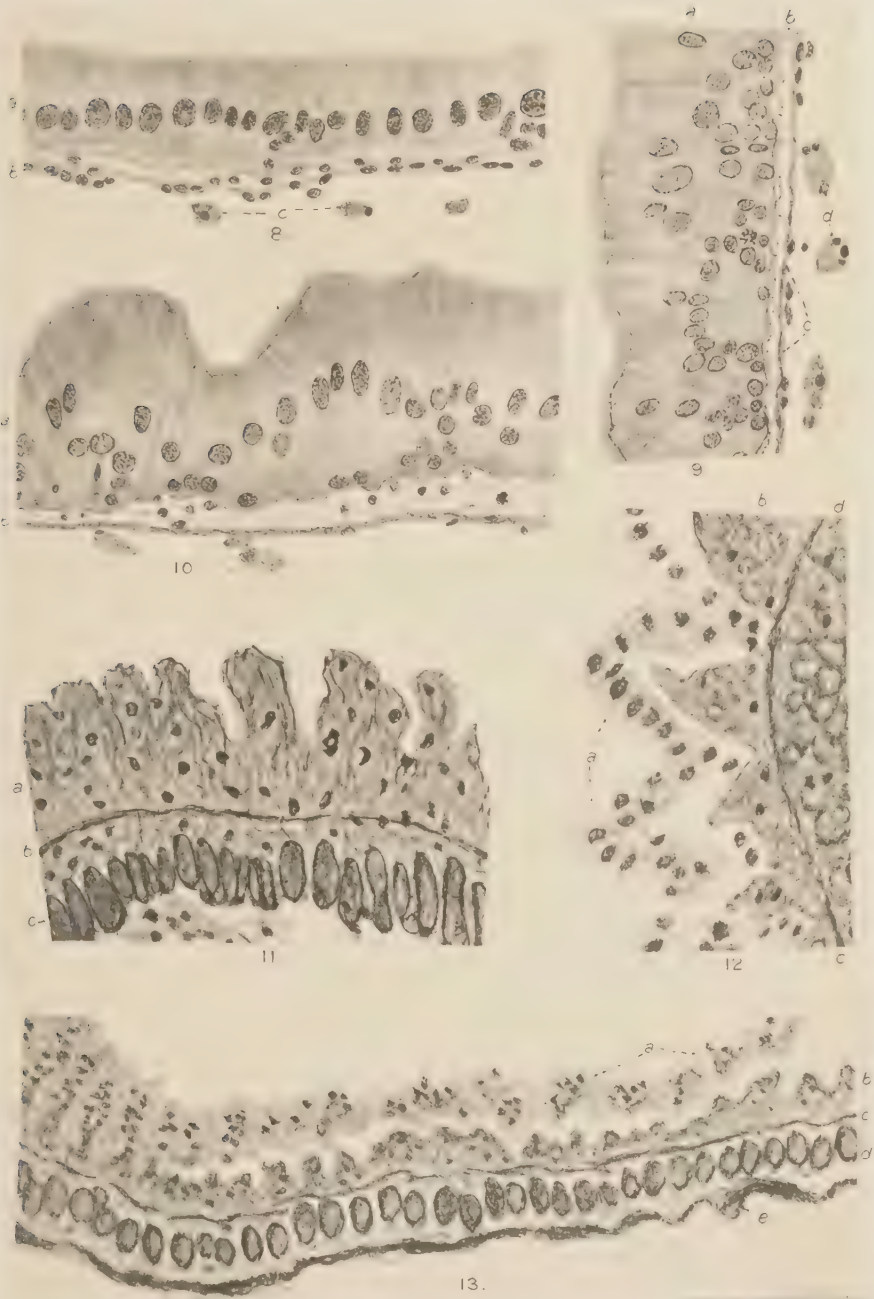


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THE ACTION OF INSECTICIDES ON THE INSECT INTESTINE.

EXPLANATION OF PLATE IV.

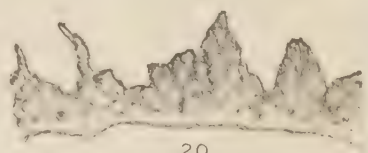
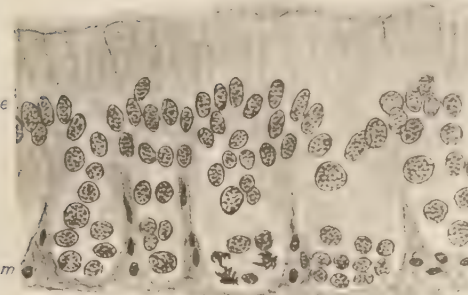
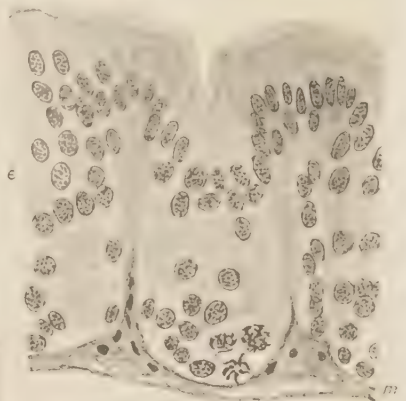
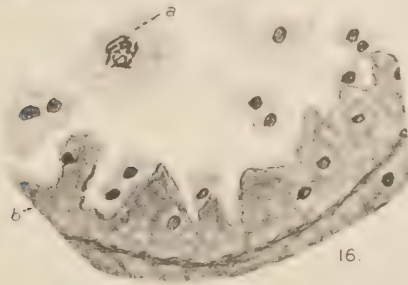
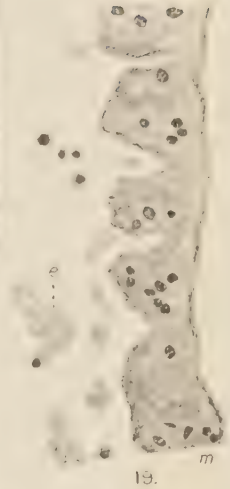
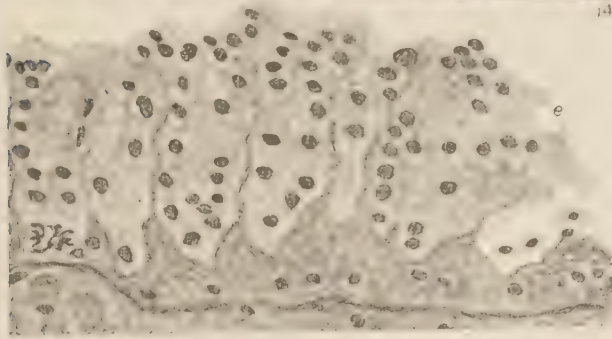
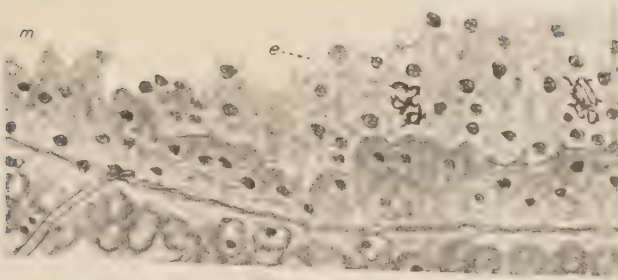
- Fig. 8. Mid-intestine of larva of locust of the 1st instar: cross-section: *a*, epithelium; *b*, annular muscular layer; *c*, outer longitudinal muscular layer; the inner longitudinal layer is not yet differentiated.
- „ 9. Mid-intestine of larva of locust of the 2nd instar, cross-section: Beneath epithelium (*a*) the inner longitudinal muscular layer (*b*) begins to be differentiated; *c*, middle annular layer; *d*, outer longitudinal muscular layer.
- „ 10. Mid-intestine of larva of locust of the 3rd instar, longitudinal section: *a*, epithelium; the inner longitudinal layer of the muscular coat (*b*) is well developed.
- „ 11. Mid-intestine of locust after poisoning with 5 per cent. Na_2SiF_6 , longitudinal section. The epithelium has totally disappeared. Here are to be seen only the connective membrane (*a*) and the muscular coat with its inner longitudinal layer (*b*) and its middle annular layer (*c*).
- „ 12. Mid-intestine of locust, anterior part. Longitudinal section, 5 hours after poisoning with 3 per cent. Na_2SiF_6 . The epithelium (*a*) has exfoliated in a large sheet from the underlying connective membrane (*b*); *c*, inner longitudinal layer; *d*, middle annular layer of muscular coat.
- „ 13. Mid-intestine of locust, posterior part. Longitudinal section, 12 hours after poisoning with 3 per cent. Na_2SiF_6 . The epithelium (*a*) exfoliated in a continuous sheet from the underlying connective membrane (*b*). On the right, portion of intestinal wall deprived of epithelium; *c*, inner longitudinal, *d*, middle annular, and *e*, outer longitudinal layers of muscular coat.



THE ACTION OF INSECTICIDES ON THE INSECT INTESTINE.

EXPLANATION OF PLATE V.

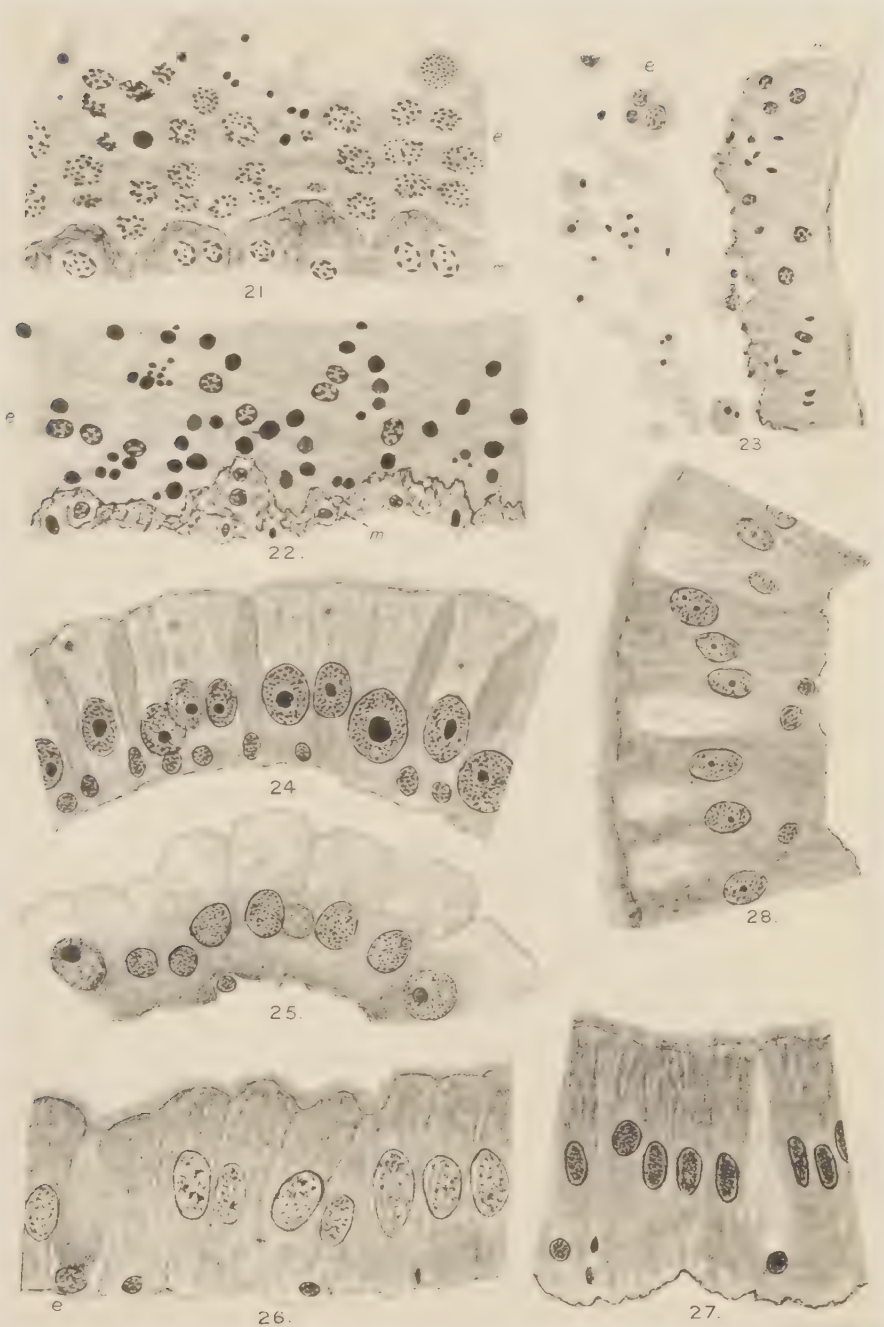
- Fig. 14. Mid-intestine of locust, anterior part. Longitudinal section, 28 hours after poisoning with 3 per cent. Na_2SiF_6 . On the right, portion of intestinal wall covered with epithelium (*e*). In the epithelium are seen two mitotic figures at the stage of loose spirems, which change into monasters. On the left, the epithelium has disappeared and the connective membrane is denuded (*m*).
- „ 15. Mid-intestine of locust, posterior part. Longitudinal section, 5 hours after poisoning with 5 per cent. Na_2SiF_6 . On the right, the intestinal wall is deprived of its epithelium (*e*). On the left, the epithelium still exists. A monaster is in view.
- „ 16. Mid-intestine of locust. Longitudinal section, 5 hours after poisoning with 3 per cent. Na_2SiF_6 . In view, exfoliated and disintegrating epithelium cells. In one of the latter a mitotic figure at the stage of a compact spirem (*a*); *b*, connective membrane.
- „ 17. Mid-intestine of locust, anterior part. Longitudinal section, 41 hours after poisoning with Paris green; only the epithelium (*e*) and connective membrane (*m*) are shown. Within the epithelium are seen mitotic figures.
- „ 18. Mid-intestine of locust, anterior part. Longitudinal section, 48 hours after poisoning with sodium arsenite (dose, 0.07 mgr.); *e*, epithelium with mitotic figures; *m*, connective membrane.
- „ 19. Mid-intestine of locust, anterior part. Longitudinal section, 7 hours after poisoning with sodium arsenite (dose, 0.08 mgr.); *e*, remains of exfoliated epithelium; *m*, connective membrane.
- „ 20. Mid-intestine of locust, anterior part. Longitudinal section, 96 hours after poisoning with sodium arsenite (dose, 0.07 mgr.). The epithelium has disappeared. Only the connective membrane is to be seen.



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EXPLANATION OF PLATE VI.

- Fig. 21. Mid-intestine of locust, anterior part. Longitudinal section, 26 hours after poisoning with Na_2SiF_6 (dose, 0.12 mgr.). Epithelium (*e*) consisting of fused cells, with nuclei of coarse-grained structure; *m*, connective membrane.
- „ 22. Mid-intestine of locust, anterior part. Longitudinal section, 7 hours 30 minutes after poisoning with Na_2SiF_6 (dose, 0.18 mgr.). Epithelium (*e*) in the form of a continuous mass with coarse-grained or compact nuclei partly breaking up into isolated lumps; *m*, connective membrane.
- „ 23. Mid-intestine of locust, anterior part. Longitudinal section, 22 hours after poisoning with Na_2SiF_6 (dose, 0.37 mgr.); *e*, exfoliating and disintegrating epithelium; *m*, connective membrane.
- „ 24. Normal intestine of Gypsy Moth (*Porthetria dispar*, L.), longitudinal section. Only the epithelium is here shown. Among pale columnar cells with a marginal hem and large-sized nuclei are seen darker calyciform cells.
- „ 25. Mid-intestine of caterpillar of Gypsy Moth. Longitudinal section, 3 hours after poisoning with Na_2SiF_6 . Here is shown only the epithelium, which has retained its normal appearance.
- „ 26. Normal mid-intestine of caterpillar of Cabbage Butterfly (*Pieris brassicae*), longitudinal section. Here is shown only the epithelium, consisting of columnar cells with a marginal fringe; *a*, calyciform cell.
- „ 27. Mid-intestine of caterpillar of Cabbage Butterfly. Longitudinal section, 5 hours after poisoning with Na_2SiF_6 (dose, 0.21 mgr.). Epithelium with dark nuclei. The pale cell is a calyciform one.
- „ 28. Mid-intestine of caterpillar of Cabbage Butterfly. Longitudinal section, 5 hours 30 minutes after poisoning with sodium arsenite (dose, 0.15 mgr.). Epithelium with nuclei, which have a lighter colour than those in fig. 27. The pale cell is a calyciform one.



Jambhakar & Carpenter, 1936, London

SECOND REPORT ON AN INVESTIGATION INTO THE BIOLOGICAL CONTROL OF WEST INDIAN INSECT PESTS.*

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*Imperial Institute of Entomology and Imperial College of
Tropical Agriculture.*

(MAP.)

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* In accordance with the suggestion of Dr. Walther Horn this report is numbered for bibliographic purposes, no. 140, in the series of entomological and ecological papers by the present writer.

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I. INTRODUCTION AND ACKNOWLEDGMENTS.

In 1931 appeared "A preliminary report on an investigation into the biological control of West Indian insect pests," as an Empire Marketing Board Grey Book (Myers, 1931). It covered the preliminary survey work from November 1928 till May 1930, when the writer went on duty to England. The present report takes up the investigation from September 1930 till the end of March 1934, when the writer became definitely seconded to the Imperial College of Tropical Agriculture.

Both for every official facility and support, and also for ever ready personal advice and encouragement I owe a debt of gratitude to Sir Guy Marshall, Director of the Imperial Institute of Entomology, and to Dr. W. R. Thompson, Superintendent of the Farnham House Laboratory. I wish to thank also Dr. S. A. Neave, Assistant Director, and the staff of the Institute for assistance of many kinds, including the identification of most of the insects collected.

As heretofore, my wife has furthered the investigation not only in the specific projects officially allotted to her, but also in every other direction. She was, however, invalided to England towards the end of 1931, with severe malaria resulting from the conditions of work in the unhealthy Delta of the Orinoco.

The Governments and planting and ranching communities in every Colony and in several foreign countries facilitated the work in all possible ways. I am indebted especially to the Principal of the College (Sir Geoffrey Evans, C.I.E.), to the Commissioner of Agriculture for the West Indies (Professor H. A. Ballou, C.B.E., followed

by Mr. G. A. Jones), to the Directors of Argiculture in British Guiana (Professor J. Sydney Dash), Trinidad (Mr. E. J. Wortley, O.B.E.), Jamaica (Mr. H. H. Cousins), and Barbados (Mr. R. W. E. Miller), and their staffs, and to the local Agricultural Officers in all the northern islands. In British Guiana, Mr. E. H. Haynes, Commissioner of the Rupununi, the Land Officer, Mr. E. E. Melville, and Mr. A. W. B. Long, Commissioner of the North West District, were exceedingly helpful. As before, I am very grateful for the generous help of all the local entomologists. I must especially mention the loyal and enthusiastic co-operation of Messrs. L. D. Cleare, H. E. Box and A. Pickles. To Mr. L. C. Scaramuzza, my assistant in the Amazon fly and *Lixophaga* campaigns, I am indebted for loyal help and much hard work. In the non-British countries I am indebted for various facilities to President Juan Vicente Gomez, Dr. R. Requena, and Dr. H. H. Pittier in Venezuela, to the officials of the School of Agriculture, Damien, Haiti, especially to Dr. H. D. Barker, and Messrs. Hebert and Leonard; to Hon. E. D. Colón, Commissioner of Agriculture, and Drs. M. D. Leonard and G. N. Wolcott, Entomologists, in Puerto Rico. In Cuba I was very especially and very generally helped by General E. Molinet, Minister of Agriculture in the Machado Government, through Señor E. Sanchez Estrada, Chief of Plant Quarantine, and Dr. S. C. Bruner, Chief Entomologist and their staffs. Jamaica is indebted to this Government and to these gentlemen for the practically costless large-scale introduction of an efficient parasite of the citrus black-fly—a parasite brought at great expense from Malaya to Cuba by the United States and Cuban Governments. In Cuba, likewise, I owe much to Dr. D. L. Van Dine, late of the Tropical Plant Research Foundation, and Señor Grau, Manager of Central Jaronú.

In foreign countries His Majesty's representatives frequently gave generous assistance far exceeding the demands of official courtesy. I should like to express special appreciation of the kindness of Mr. W. E. O'Reilly, then British Minister in Caracas, Mr. J. H. Magowan, then Chargé d'Affaires in Haiti, Mr. F. G. Coultas and later Mr. S. C. Lawrence, H.M. Consuls in Para, and Mr. Turner, H.M. Vice-Consul in Manáos, and his very efficient secretary.

To Mr. Cunningham, Chief of the British Guiana Boundary Commission, to Dr. Don L. F. Vegas, Chief of the Venezuelan Boundary Commission and their staffs (especially Mr. T. Orella), to the Fathers of the Benedictine Prelazia of the Rio Branco, to Don Mario Dias de Sousa Cruz, of Viçosa, and to Dr. Don L. Fernandez Peña, of Uairaen, I am indebted for great courtesy and much material aid.

The officials of the Empire Marketing Board, up to the time of its demise, were especially helpful.

To the officers of Pan American Airways, from the Bahamas to Pará, I am indebted for unfailing courtesy and ready assistance, especially in the transport of parasites.

My secretary, Miss E. Fraser, has been of inestimable assistance in the care of records and collections and in the preparation of reports.

Finally, I have been assisted in the various aspects of work and travel by many other officials and private individuals, too numerous to mention by name.

II. GENERAL CONSIDERATIONS ON BIOLOGICAL CONTROL.

1. Technique.

The plan of work has been essentially the same as described in the previous report—firstly, to collect general ecological and agricultural data on the regions visited, with a view to correlating them with the incidence of pests; secondly, to obtain a notion, expressed where possible in figures, of the status of every pest;

thirdly, to discover by dissection, rearing and field observation its natural parasitic and predacious enemies, and to ascertain the average mortality caused by each; fourthly, to study the life-history and ecological requirements of the several natural enemies with a view to their possible utilisation; and fifthly, to see whether any other natural or artificial (e.g., agricultural) limiting factors are operating. In the course of this work some 24,000 further dissections and examinations have been made.

2. Ecological Considerations.

Much greater emphasis has been placed on the two ecological considerations which were to a great extent new when the preliminary report was published. I cannot sufficiently underline their importance here. The first is the principal of ecological islands and the second is the notion of a primitive, pre-economic habitat; both concepts were unfamiliar to the biologist working in North America or Europe, where the tendency of civilisation is to break down ecological barriers and to eliminate primitive plant-associations. In biological control work the forgotten dictum of Grant Allen that "the tropics are biological headquarters" is especially and very practically true. It is a curious fact that while astronomers and meteorologists go to tremendous expense to establish permanent stations in the most inaccessible regions of the world, where conditions happen to be ideal for their investigations, biologists are largely content to study what Wheeler calls the depauperate glacial fauna of the laboratory or to confine their interests to the artificial and mutilated animal and plant associations of the older civilised northern countries, eked out by the study of preserved material and by hasty visits to the tropics, often too short to acquire that intensive local knowledge so essential to valid ecological work. To this regrettable tendency the Imperial College of Tropical Agriculture and the several biological stations founded in the American tropics, chiefly through the initiative and enthusiasm of Professor Thomas Barbour of Harvard, present notable exceptions.

In the West Indies and on the mainland ecological islands are exceedingly well-marked. The close ecological unity and isolation of the British Guiana cane-lands has been already described. Further analysis shows both natural and artificial factors. The forest and the great rivers—from the Corentyne to the Essequibo—are original barriers. The original covering of the present coastal flats, as may be seen immediately behind the cane-lands at the present day, was a "wet savannah"—a swamp in fact, which has been briefly described in an ecological article (Myers, 1933). Continued investigation has shown that this wet savannah, with the patches of swamp forest which occasionally diversify it, and into which, further inland, it finally blends, could not, as I at first mistakenly supposed, have been the original home of the cane-borers (*Diatraea* and *Castnia*). As regards the former insect, the present wild plant-hosts are actually restricted to artificial induced associations, namely the weed-grasses of dam beds and the special water-grasses of the trenches, both of which were represented in the original vegetation, if at all, by very limited and scattered societies.*

In the interior, natural ecological islands, with very distinct limits, are formed by the savannahs, by their bush-islands and by the blocks of high land culminating,

* There is even evidence (cf. Richard Schomburgk, 2, p. 387) that some at least of the water-grasses were introduced. Thus Schomburgk states definitely, of the floating grass-beds in the Demerara River, "This peculiar sedge-like grass, which had only become indigenous on the river a few years before from the Orinoco, was brought here by the cattle with which the districts bordering that river supplied Georgetown, the beasts being fed on it during their transport by water. After the sale of the cattle, one usually threw the fodder that remained into the river." He identified it, in the absence of flowers, as probably a species of *Panicum*, a term which in those days might have included *Echinochloa*, *Paspalum* or *Panicum*, and the three commonest water-grasses belong to these three genera. The editor calls it "Freeman's grass" and "Musuri" or "Missouri grass." The latter is an indefinite Creole term applied to various water-grasses.

in the region so far traversed, in the 9,000 feet summit of Mount Roraima, already famous for the highly endemic nature of its fauna and flora.

If the theory and practice of biological control are to advance, the original concept that success can be expected only where the pest is introduced into a new country without its parasites, which may then be brought in, must be modified in both its parts. This notion has already been dealt a severe blow in the spectacularly successful control of the Fijian coconut moth, an apparently indigenous insect, by an introduced parasite of a rather slightly related insect elsewhere (Tothill, Taylor & Paine, 1930). There is surely no valid ecological or practical difference between a pest introduced without its parasites and an indigenous insect which, in a circumscribed biological or geographical island, has learned to live upon a cultivated crop, while its parasites, although perhaps already abundant in the area, even on the edge of the fields, have not yet learned to or are in some way prevented from, attacking it in its new host-plant.* The line of control endeavour should here take the course, not of trying hopelessly to establish the parasites in the cultivations, but, in accordance with the older and proven technique, of introducing another and more efficient parasite from outside.

This brings us to the question of the utilisation, by mass-breeding, of indigenous parasites already attacking the pests in the cultivations. This procedure is still in the experimental stage, and its suggested benefits the subjects of controversy—a controversy which has had the very desirable effect of stimulating exact experimental work from which, before long, it should be possible to assess the value of this form of biological control.

3. Importance of Studying Primitive Conditions.

Referring now to the importance of studying a pest under primitive conditions, I still find planters and others surprised that, in my search, for example, for cane-pest parasites, I do not concentrate on the greater cane-growing districts of the region, instead of spending so much time in "the bush." While this allegedly incommensurate attention to uncultivated regions is only partly due to the necessity of studying primitive habitats, being also the result of travelling difficulties, connected both with transport and food supply in relatively unexplored districts, it may be abundantly justified to the practical man, if only by the fact that the most promising parasite so far discovered, the Amazon fly (*Melagonyistylum minense*), was first found, not in sugar-cane, but in a wild host-plant, in a primitive plant community. With the progress of local entomological services in cultivated regions there will be less and less likelihood of a visiting entomologist's discovering new parasites there. In the search for efficient parasites tropical South America offers unique opportunities, since it possesses a larger extent of unmodified and undeveloped country than probably any other part of the world, at least outside the polar regions.

4. Inferior Efficiency of Egg-Parasites.

The question of the type of parasite which is most promising has also been considered, in view of several misconceptions that prevail. It is frequently stated in entomological publications that an egg-parasite is the most desirable and efficient form, for the reason, implicit or expressed, that it kills the pest-insect before this

*A very apposite case in point is that of the western wheat-stem sawfly (*Cephus cinctus*) in Canada. Criddle (1922) has shown how the extensive planting of wheat provides a new habitat for this indigenous insect, where its larvae are nearly immune from the attacks of the local parasites, which often effect a very considerable mortality in its grass-hosts. To meet this situation, Dr. W. R. Thompson and Dr. G. Salt, of the Farnham Royal Laboratory, shipped to Canada vast numbers of the parasite, *Collyria calcitrator*, which, according to Salt (1931) shows "perfect adaption to and complete concentration on" wheat-feeding Cephids of other species in Europe. This experiment gives every sign of becoming a great success.

has done any damage. This is to look at parasitic control as essentially similar to mechanical control; and to overlook the advantage of the former. The view seems to be that, as the operation must be performed every year, it is best done before the pest has had time to commit its depredations. Actually, however, since biological control, if successful, permanently reduces the pest to non-economic status, the stage at which the parasite attacks it is quite immaterial.

In point of fact there are several reasons, one historical and two biological, which render, in general, and other things being equal, an egg-parasite less promising than a larval one. The first reason is that there seems no outstanding case in the annals of biological control of successful control by means of an introduced egg-parasite.* The second reason is that in many pest-insects, especially among the caterpillars of butterflies and moths, the young larval mortality is extremely high; so that a correspondingly large proportion of the insects killed in the egg, would have perished in any case soon after hatching, the *effective* parasitism being thus greatly reduced accordingly. A larval parasite on the other hand, tends rather to kill the host after it has largely passed the risks of young larval mortality and of later life. Larval parasitism is thus more effective in that it is cumulative on the effects of other causes of mortality. The third reason for the lesser efficiency of egg-parasites lies in the greater tendency of these towards polyphagy, extending even to frequent hyperparasitism. In other words egg-parasites in general are more liable to dissipate their energies over a number of hosts, many probably non-injurious, rather than concentrate upon the pest-insect. Larval parasites, on the other hand, tend to be much more specific. Some observers actually regard polyphagy as an advantage in that the parasite is thus enabled to maintain an effective population at seasons when the pest is scarce. Experience has, however, shown that this is quite unnecessary. Moreover not one of the great successes of biological control has been won by the employment of a markedly polyphagous parasite or predator. Success has been in direct proportion to specificity, and will probably continue so. Howard & Fiske (1911, p. 204) and Wheeler (1928, p. 6) have both stressed the necessity for specificity in the parasites utilised. The ability of a parasite, however, to parasitise the same pest-insect on several different host-plants, including wild plants, is quite another quality, and is eminently desirable.

5. Parasites for Boring Insects.

Many of the most important pests of the region are boring insects, and for these I am coming more and more to believe, on empirical considerations, that the most promising parasites are Tachinid flies. In the case of sugar-cane especially, the thick stem of the new host-plant seems to present insuperable obstacles to the efficiency of Hymenopterous parasites, which have to pierce it with the ovipositor. Those Tachinids, however, that deposit young larvae at the mouth of the boring are in no way so handicapped. It is highly significant, as I have shown in my preliminary report, that most of these boring pests, notably the small moth-borers,

* The case of *Cyrtorhinus mundulus* in Hawaii is only an apparent exception to this rule. This *predacious* bug is of the greatest value in the control of the cane-leathopper (*Perkinsiella saccharicida*); but it differs from most egg-parasites (strictly, *parasitoids*) in being, as Muir very carefully ascertained before introducing it, strictly confined not only to this one host, but also to the one host-plant, sugar-cane. The late Dr. Muir once told me that he spent several sleepless nights considering the risks of the introduction should the bug not remain faithful to these traits in its new home.

A more nearly valid exception is afforded by the egg-parasites which supplied a measure of control for *Perkinsiella* for a number of years, but had eventually to be reinforced and finally superseded by the introduction of *Cyrtorhinus*. Their considerable though temporary measure of success was probably related to their host-specificity, which is greater than the average for egg-parasites. The egg-parasite (*Anaphoida gonipteri*) introduced from Australia against the *Eucalyptus* leaf-weevil (*Gonipterus scutellatus*) appears to be successfully established in parts of South Africa, where results will be awaited with interest.

the cocoa-beetle and the mahogany-tip borer, are attacked already by a long list of Hymenopterous parasites, which, at least in the cultivated host-plants, are largely ineffectual, though controlling the insect in wild hosts.

Thompson (1929) has studied mathematically the question of parasitic control for insects living in protected situations. He concludes that "other things being equal, . . . the fact that a proportion of the host population is inaccessible may have an extremely serious effect on the progress of its parasites. Even though the parasite reproduces at a rate which enables it to reach the numerical level of the accessible host population in a short time, the fact that a relatively small proportion of the hosts is inaccessible may completely prevent it from establishing control."

6. The Origin of Pest Insects.

In the preliminary report I wrote that "the prevailing impression from a study of West Indian agricultural pests is one of constant flux," in that the attacks even of native insects are in many cases of very recent origin, while the introduction of new cultures and pests into areas where they were absent has caused further drastic changes. I wrote then that it is time these ecological transmutations, where possible, were carried out less blindly, and with an eye to biological consequences. Some preliminary study has been made of the factors influencing the passage of an indigenous potential pest-insect from a wild host-plant to a cultivated crop. The most important factors may be summarised as follows, as far as possible in the order of importance:—

(1) *Range of the insect's host relations under primitive conditions.*—A certain tendency towards polyphagy is a *sine qua non* for a potential pest. By hypothesis, an obligate parasite of one wild plant species cannot become a pest unless its host acquires economic value.

(2) *Botanical affinity of the crop-plant with the wild hosts.*—From the practical point of view, we ought, for instance, to regard nearly all tropical grass-feeding insects as potential cane pests.

(3) *Ecological resemblance of the crop to wild plant associations.*—I have elsewhere (Myers, 1926 *a, b*) shown that certain groups of insects, for example, very many of the phytophagous Homoptera, are attached rather to plant-associations than to plant-species, while the reverse is the case with many phytophagous Heteroptera. A corollary of this is that crops with a wide adaptability to differing ecological conditions, *e.g.*, sugar-cane, are liable to be attacked by a greater variety of pest-insects than a less adaptable crop such as cacao. Extending this example, one finds that while the various species of *Diatraea* are confined rather closely to certain wild plant-associations, several have learned to thrive in cane-fields.

(4) *Proportion of area of crop as compared with wild plant-associations.*—One of the stock explanations of the increase of insect pests is that large monocultures offer a tremendous increase of one particular host. They tend also to encourage the passage from the wild to the cultivated crop. I have elsewhere shown that, in the American tropics at least, peasant crops are much less liable to mass-attack than the same crop grown under large estate conditions. In the Delta of the Orinoco (Myers, 1932 *b*) although cane has been grown in tiny provision patches of the aboriginal Indians, scattered and isolated in a vast extent of swamp-forest, for at least 300 years, the small moth-borers (*Diatraea*), although plentiful in the large areas of aquatic grasses, have apparently not yet learned to attack this crop. Similarly, in the Amazon, where the area of sugar-cane is infinitesimal compared with the vast areas of floating grasses, it is hardly possible to find major infestations of mealy-bugs, of froghoppers (*Tomaspis*), of borers (*Diatraea*), or of ants on sugar-cane, though immense populations of all these insects occur in the surrounding grass-associations.

There is an apparent exception to the greater infestation of pure stands, in the case of the borer, *Castnia licoides*, which I have shown, is much less abundant in the huge, uniform pure stands of its wild host, *Heliconia Bihai*, which are a feature of a certain type of Guiana second-growth bush, than in the more isolated plants growing in the virgin forest. This exception is doubtless explicable under the predominating influence of factor (3), but it has not yet been analysed.

(5) *Length of time the crop has been grown in a given area.*—Naturally time is necessary for the passage to a new host-plant. The amount depends largely on the influence of factor (4).

Doubtless thoughtful workers elsewhere will at once be able to augment the above list, which is offered merely to stimulate research upon this important and neglected aspect of applied entomology. The problem has received some attention in Canada from Atkinson (1931), who analyses rather the causes which have led to the increase of certain indigenous pest-species after they have learned to attack crops. He comes to no conclusions of general application, save that the five species dealt with have all increased, firstly, because of increased food-supply, and secondly, because of a number of advantages, different for each species, presented by the new habitat of cultivated fields. Grasshopper outbreaks occurred before the advent of agriculture; therefore, they have not increased proportionately so much as the other four species. Cook (1931) attacks the parallel problem of predicting the future distribution of introduced insects. His prophecies are, however, based on the by no means valid assumption that "in a general way, . . . the distribution of any single organism is governed by climatic conditions." With Grinnell and his collaborators (1930) we believe, on the other hand, that "some biotic or physiographic influence (not now measurable) may have more importance for the distribution of a particular animal species than any of the physical factors capable of being expressed in quantitative form." For the same reason the writer has continued to employ his former technique of assessing the environmental factors by means of the vegetation, rather than by meteorological measurements, since the plant communities are influenced by the sum total of these factors, including the unmeasurable ones.

The need for intensive local ecological research on the pests to be controlled has been again exemplified. Investigators engaged in this work are in a splendid position to receive and to establish parasites sent to them from other regions. It is not too much to say that without the co-operation of Messrs. Box and Cleare, in the *Lixophaga* and Amazon fly campaigns respectively, it would have been impossible to achieve success. Their preliminary survey work, moreover, forms the necessary basis for an evaluation of the economic effects of these introductions in years to come.

III. ITINERARY AND TRAVELLING CONDITIONS.

Travelling, on the search for parasites, on projects of actual introduction and on advisory work, has been almost continuous during the three and a-half years covered by this report.

The British Colonies of the American tropics have again nearly all been visited, and in addition a month was spent in the Bahamas to advise the Government on the sandfly pest. Collection of parasites on a large scale has been made in Puerto Rico, Cuba and Haiti; and a further search for parasites made in Haiti and the island of La Gonave. Santo Domingo, probably the most promising Antillean country for parasites, has again, unfortunately, been greatly neglected. Excellent results would undoubtedly accrue from three months' work there. Some idea of the pest-parasite situation was obtained at one point in Colombia (Santa Marta) and one in Panama (Colón), *en route* to and from Jamaica.

The general explorations for parasites on the South American mainland may be summed up under five journeys, as follows :—

(1) From Trinidad to La Guaira, Venezuela, thence to the valley of Caracas, Maracay, and the Lake of Valencia, the coast valley of Ocumare de la Costa, and finally from Caracas south across the llanos to San Fernando de Apure. On the return from La Guaira various points along the north coast were investigated, ending with Carúpano, ecologically similar to parts of Trinidad.

(2) From Georgetown to the North-west District of British Guiana and thence by the Yarikita and Amakura Rivers into the Delta of the Orinoco.

(3) From Trinidad to Pará, thence to the great ranching island of Marajó, returning, exploring the River Mojú, and then ascending the Amazon. Ascent of the Tapajoz for 120 miles ; continued ascent of the Amazon to Manáos ; thence up the Rio Negro and Rio Branco to the Brazilian border of British Guiana ; from there, by the head of the Ireng and that of the Mazaruni River to Mount Roraima, in Venezuela, returning by the Venezuelan and Brazilian savannahs to the River Uraricuera, flowing into the Rio Branco. Thence, owing to lack of communication with Manáos, I returned to the British Guiana border and walked down the Cattle Trail to the coast, exploring all plant associations for parasites *en route*. In all about 800 miles were covered on foot—a method of progression which offers the best condition for entomological work, and one which ought to be adopted more generally, were the time available.

(4) From Georgetown, up the Essequibo River, and over the watershed into the Ireng River, the boundary between British Guiana and Brazil, and down the latter to Santarem and Pará on the Lower Amazon *via* the Takutu River, Rio Branco, Rio Negro and Amazon.

(5) From Santarem to the border of British Guiana by the same route. Two journeys from the British border into the little-known Kanuku Mountains, and one to the still less known Shiriri Mountain. Finally return to Georgetown down the Essequibo River.

Of the three main difficulties in South American travel, namely, rapids, disease and shortage of food, the writer has at least had his share. With a few notable exceptions, involving desertion under difficult conditions, the labour employed, Latin, negro, East Indian, aboriginal Indian and mixtures of several, after judicious selection, proved trustworthy, hardworking and intelligent, those with aboriginal blood being by far the most efficient in entomological work and attaining a very high degree of skill in particular jobs.

Grave difficulties and delays were encountered in Brazil (and there only) as a result of recent restrictions on research and exploration by foreigners. Through the kind offices of the Ambassador in Rio de Janeiro, and of the local Consuls, these were finally overcome. On my return journey from Santarem, however, I was permitted by the Manáos authorities to travel up the Rio Branco only on condition that I gave my word of honour to do no scientific work *en route*.

In these primitive regions the fashionable ecologist, who believes that the progress of his science lies only in the accumulation of quantitative data, expressed in bleak mathematical terms, must perforce curb his impatience until reconnaissance studies in taxonomy, chorology, and merely qualitative ecology have been made ; for even these are largely lacking.

IV. ECOLOGICAL CONDITIONS IN THE REGIONS VISITED.

1. General Considerations.

In the preliminary report a fairly detailed ecological survey was made of the West Indian islands. This was rendered possible by the relatively small areas

concerned and by the existence of a considerable body of published information which was freely drawn upon. During the period now under review, explorations were chiefly confined to the mainland of South America, and to two countries—Venezuela and Brazil—of such vast extent, with so much unexplored territory, that general statements are valueless, and the following notes are therefore perforce confined to the conditions actually experienced in the regions visited. To avoid overlapping and save space, the comparative ecological notes on crops, which in the preliminary report were scattered in the body of the work, under the crop-headings, are here put together in the general account of each area, under the headings, geography, meteorology, vegetation, agriculture and pest-situation.

The details of the itinerary having been noticed in section III, the regions visited may be summed up as follows:—(1) the north coastal region of Venezuela, representing the chief cultivated areas of the Republic; (2) the Venezuelan llanos; (3) the Delta of the Orinoco; (4) the interior of British Guiana; (5) North Brazil, along the Amazon Valley, and east of the Rio Negro and Rio Branco; (6) the Santa Marta district of Colombia; (7) the Colón district of Panama; (8) the Bahamas.

In altitude the investigation has so far proceeded from sea-level to about 9,000 feet (the Silla of Caracas and Mount Roraima).

2. Biological Factors.

In the preliminary report some seven pages were devoted to the tremendous effects, in the West Indian area, of the introduction of foreign animals and plants. In the mainland areas covered in the period under review, there is a marked contrast to this state of affairs. In the forest areas of Venezuela, Amazonia and Guiana the influence of imported organisms, including man, has been practically nil save in the relatively tiny areas which have actually been cleared and cultivated. The extent of fires has been certainly increased by the advent of man, though spontaneous fires are by no means infrequent (Viosca, 1931), but the population over a large proportion of the area is mainly aboriginal Indian, whose influence in this direction has been exerted from time immemorial. The only marked effect of imported organisms in the savannah areas of the above region has been the modification of indigenous plant-associations, and even their replacement by less economically valuable ones (induced associations of weed species) by grazing stock, notably cattle and horses. These were introduced in the Venezuelan llanos in 1530 and 1521 respectively (*cf.* Myers, 1933, p. 341); in the Rio Branco savannahs in 1796 and in the Rupununi savannahs of British Guiana about 100 years ago (as strays from the Brazilian side, for settlement began scarcely forty years ago). In the latter case their concentration has not yet reached a figure sufficient to modify the original vegetation save in the immediate vicinity of houses, corrals and fences.

Light burning of the grasslands, even in the most thinly populated districts, is almost universal and has been so from time immemorial, independent of European influence. There is considerable evidence that the present savannah vegetation represents a fire climax, at least to some extent originated and maintained in its present constitution by the frequent burning. In this connection it must be emphasised that the originally almost complete absence of large grazing animals, save a few negligible deer, is in marked contrast to the conditions prevailing in the grasslands of other continents, and leads without fires to the inordinate accumulation of roughage.

The mongoose, and a small whistling frog from Barbados, have been introduced and established in the coastal cane-lands of Demerara, but are still in insufficient numbers to affect the biological balance save in extremely limited areas. Rats, apparently of introduced species, have at times been highly injurious in the same cane-areas.

Certain poison-plants (other than those, such as *Lonchocarpus* spp. which grow wild) have been introduced and cultivated by the Indians and used for poisoning

bodies of water to kill fish, but the effect on the local fish-fauna seems to be only temporary. Other plants introduced or distributed and cultivated by the Indians, for example plantains, bananas and sweet potatoes, have established themselves locally as wild plants.

The comparative scarcity of introduced insect pests on the imported citrus and other plants in the Rupununi District of British Guiana has been remarked in another place (Myers, 1934 *b*) and is explained by the fact that most of these plants, owing to transport difficulties, were brought in as seeds. A great contrast is afforded by the equally ecologically isolated plantations of Henry Ford on the Rio Tapajoz, where the introduced plants, especially citrus, suffer very badly from the attacks of exotic scale-insects and other pests, brought in with the plants without quarantine or supervision.

3. Northern cultivated and coast Areas of Venezuela.

Observations were made in the Valley of Caracas, and westward to Maracay, Valencia and over the coastal Cordillera again to Ocumare de la Costa; at La Guaira, Guanta, Cumaná, Pampatár and Carúpano, eastward along the coast towards Trinidad. All these districts, plus parts of Colombia that I have not seen, are included in the North Andean Crops and Grazing Region in the very useful classification drawn up by Jones (1930), but that it is not a very unified region is indicated by his remark that "few areas in South America exhibit such sharp contrasts within short distances." He mentions deep fertile humid tropical valleys, hot gorges supporting cactus and thorn-forest, and steep highland slopes planted in coffee, higher areas with temperate cereals and verdant pastures, heath-clad páramos and finally the eternal snows of the Cordillera. In the following section, for the sake of clearness, I have treated separately the four main districts visited in the present investigation. There the maincrops are coffee (the most important export crop of Venezuela), cacao and sugar, with much maize as a local food-staple. In the latter category beans and peas (especially *Vigna inguiculata*) are second only to maize, while plantains and bananas are also highly important.

The Valley of Caracas.

Geography.—Running parallel with and just to the north of the highest ridge of the coastal Cordillera, the Valley of Caracas lies at an elevation of 2,933 feet at one end (El Paraíso) and 2,833 near the other (Petare). The culminating peaks of the Cordillera (La Silla, 8,800 feet, Pico de Naiguatá, 9,217 feet) tower over it to the north, but the hills to the south of it are lower, the main road passing over the saddle at Los Teques at an elevation of 3,900 feet. The valley is fertile and fairly well-watered.

Meteorology.—The climate is lauded as one of perpetual spring. To me it seemed foggy, chilly and unpleasant even in the dry season. The average annual rainfall of Caracas for the seven years (1920–1926) was 34 inches. Hennig (1913, p. 318) records 32 inches, as a 16 year average, the wettest months being July (with 5 inches) and October (with 4½ inches) and the driest, February (with 0.3 inches) and March (with 0.6 inches). The whole area is under the influence of the monsoon, which governs the regime of rainfall and causes a strongly marked seasonal rhythm, a dry season from November to April and a wet one from May to October. With regard to the temperature, the Valley lies just below the upper limits of the tierra caliente, which enjoys a mean temperature of 71° to 82°F., the lower figure being thus applicable here. According to Hennig (1913) in Caracas the mean temperature of the warmest month is 73.9°, and of the coldest month 68.5°F. The daily range of temperature varies increasingly with the altitude, and at Caracas is very marked, the nights being distinctly cold and the days hot, until a cloud passes over the sun, when one is instantly chilled.

*Vegetation.**—The vegetation has been profoundly modified by deforestation. Common plants of wasteland, and roads in the valley itself are the trees, *Cedrela mexicana*, *Guazuma ulmifolia*, *Mangifera indica* and *Triplaris* sp., bananas, the bushes, *Psidium guajava* and *Acacia macracantha*, the herbs and grasses, *Stachytarpheta mutabilis*, Guinea-grass (*Panicum maximum*), *Pappophorum alopecuroides*, *Sporobolus indicus*, *Paspalum fimbriatum*, *Eleusine indica*. The complete absence of the tall razor-grasses, *Paspalum virgatum* and *P. millegrana*, is striking. The general facies of the vegetation is strongly reminiscent of the *Guazuma*-guava-Guinea-grass association which occupies so much cleared forest-land in southern Cuba. Towards Guatire some of this mesophyte forest remains and is brilliant with the large tree-daisy *Oyedaea verbesinoides*.

Tall beds of arrow-grass or Caña amarga (*Gynerium saccharoides*) form a marked feature of the stream-banks. They are used to hold up the banks, while the stems are sold for roofing, to support tiles. *Tillandsia usneoides* is common on trees, and another species grows thickly on telegraph wires in the city. *Cattleya labiata* is able to flower vigorously on the trees in the Plaza.

The slopes above the cultivations to an altitude of about 4,000 feet are largely clothed in an odorous expanse of the introduced grass, *Melinis minutiflora*. Above this, especially on the ridges, is a dry indigenous pasture, with *Paspalum stellatum*, and *Andropogon* and some dozen other thin grasses, and the sedge *Dichromena ciliata*. The still higher slopes and the ravines are occupied by cloud forest, fringed with bright yellow tree-daisy (*Oyedaea verbesinoides*).†

Agricultural ecology.—Cane is the chief crop on the bottom lands, and coffee (more important) on the lower slopes. Mendoza (1924, p. 35) considers that most of the cane soils of the Valley are "tired." With regard to Venezuelan sugar-cane cultivation in general, Pittier (1926, p. 160) remarks that what Humboldt wrote more than 100 years ago might have been written only yesterday. In the Valley of Caracas the chief cane variety is known as Salangor, of which white and striped sub-varieties are distinguished. It is a very soft cane which requires little milling, and is used chiefly for making crude cane spirit or aguardiente. This may be the Batavia cane mentioned by Humboldt (cited by Pittier), which already in his day was grown chiefly in the Province of Caracas and used for making rum. Another common cane is called criolla, and is harder and pale greenish. The variety Santo Domingo seems to be the same. It is said to be sweeter, and is used almost exclusively for making papelón, or crude brown block sugar. Humboldt considers it the original form which was introduced first into the Antilles from the Canaries. A few fields of B.H. 10,12 seemed to be flourishing. Sometimes beans are planted between the rows. Some estates manure with great care—either cattle-manure (the animals bedded with bagasse) or mixtures of goat-manure, river-silt, phosphates, blood, bone, tobacco waste, ashes, town rubbish, etc. Where there is much trash, it is burned *after* cutting, unless there is much pica-pica (*Mucuna*?) in which case the field is burned *before* cutting. Ordinarily trash is gathered into barns. Cutting and grinding continue throughout the year. Mosaic is sometimes very prevalent.

The most abundant cane-field weeds are nut-grass (*Cyperus rotundus*), *Eleusine indica*, *Amaranthus* sp., *Oxalis latifolia*, the yellow-daisy, *Sclerocarpa coffeaecola*, and the introduced *Plantago major*; on paths between cane-patches, *Eleusine*, *Cynodon dactylon*, Guinea-grass, guava, *Sida* sp., *Thunbergia alata*, *Portulaca oleracea*,

* Pittier's *Manual* (1926) is a most useful guide to the commoner plants of Venezuela.

† For the purposes of this tropical investigation we are not greatly concerned with the higher slopes of the Silla and associated mountains. Suffice it to say that a large part of the cloud-forest zone is the seat of a peasant industry, growing many temperate zone fruits and flowers for the Caracas market, and offering a home to numerous introduced northern weeds. Above this the forest passes into mountain scrub and this into the windswept, alpine páramo, or heathland, with low *Arundinaria*, *Espeletia* and *Ericaceae*.

Sonchus oleraceus, and in damper spots, *Paspalum conjugatum*, Pará grass, *Commelina* sp., *Equisetum* sp.; in ditches, *Cyperus articulatus* and *Eleocharis geniculata*. A common weed in the higher *Sorghum* patches is *Parthenium hysterophorus*.

The chief pasturage is Guinea-grass (here called "gamalote"). Pará grass occurs in damper places, here and there. Much of a small *Sorghum* is grown on the flats and lower hills for the stock.

Coffee, though still the chief crop, is less extended than formerly. At one time it was widely planted on the flats and lower valleys, where it flourished until 1913, which began a series of dry years with no longer dependable rains. The shade-trees of the coffee plantations suffered badly, especially the *Inga* (the samán, *Pithecolobium Saman*, standing it well), and the coffee accordingly. We saw some of these plantations, still in a very bad condition, since the rainfall is now said to be definitely too low for coffee. They were dotted with the trunks of tall dead shade-trees. Three tall species of *Erythrina* are also popular as coffee shade, but on account of their large size and excessive food-requirements, neither these nor samán are recommended. Mendoza states that much coffee is grown on unsuitable soils. A common weed in the coffee plantations is a grass, *Chloris paraguayensis*. On some estates the planting of Bourbon coffee is being extended, in preference to the widespread Criollo. It is said to bear better and to be of equal quality. Both are forms of *Coffea arabica*. On the better estates the coffee crop is handled in a very careful manner, with elaborate cleaning and grading plants and final hand-picking to eliminate defective grains.

According to Pittier (1926, p. 152) the minimum annual yield per tree (throughout Venezuela) is 230 grammes, whereas in Central America, under no more favourable conditions, it is 500 grammes.

Pests and associated animals.—Insect pests are strikingly little in evidence on any of the main crops. Small moth-borers (*Diatraea* spp.), though present in cane, were so scarce as to be not only economically negligible, but even very hard to find. Alternate host-plants are almost entirely lacking, but Barbados, where grass hosts are equally rare and borer, on the other hand, abundant, shows that there is no necessary connection between this and borer incidence. *Tomaspis*, a species very closely related to the Trinidad froghopper, was found in two small infestations, on cane and grasses, but is still less a pest than *Diatraea*. *Castnia licoides* is present but very rarely attacks cane.

Practically the only coffee-pest is *Leucoptera coffeella*, and that is of no importance, being hardly abundant enough to cause commercial damage.

There is considerable rat-injury to canes. In one count of 100 stalks, 6 per cent. were badly gnawed. In other countries rat-injury is often secondary, following borer damage. Here it must be primary. Traps and poisons are employed.

Vertebrate enemies of insect pests are surprisingly rare. Small birds are scarce, the only abundant bird in cane-fields and other cultivations being a small ground-dove (*Chaemepelia*). The turkey buzzard (*Cathartes aura*) and the black vulture (*Catharista atrata*) are much in evidence, but such useful insect-eaters as the kiskadees (*Tyrannus* 2 spp., *Pitangus sulphuratus*), and the blackbirds (*Holoquiscalus*) are seen only at rare intervals, chiefly about the cow-yards. A few swallows and finches practically complete the list.

Lizards are still scarcer. In some seven days' work in cane-fields I kept strict watch for both leaf-lizards and ground-lizards. Of the former I saw none, and of the latter only three *Ameiva* and two undetermined ground-lizards. To this list may be added one small toad. On the upper slopes above the cultivations, ground-lizards, especially *Ameiva*, were distinctly more abundant (five observed in two hours). Rattlesnakes were said to be abundant on the lower slopes, but I saw none. Aestivation may have accounted for some of this scarcity of reptiles at the time of our visit.

Maracay and Valencia.

Geography.—Lying further west in the leeward slopes of the Coastal Cordillera, between the main range of the Serranía del Interior, this is a broad valley basin (area 1,170 sq. miles) surrounding the large and beautiful Lake of Tacarigua or Valencia (200 sq. miles in area), whose margins are fast receding and exposing rich flats for agriculture. The elevation of the lake itself is approximately 1,400 feet above sea-level.

Meteorology.—The average annual rainfall recorded at Valencia itself for the seven years, 1920 to 1926, was 40.6 inches. It is unfortunate that I have no figures for relative humidity, for it seems more than probable that this advantage over Caracas of 7 inches of rain is offset by the frequent fogs and mists of the latter locality.

Vegetation.—On the journey by road to Maracay one passes first over the saddle at Los Teques. As one rises, the Guinea-grass fields, with scattered mango and *Inga* trees and bushes of yellow tree-daisy, give place to thin pastures, with some *Melinis*; while the river fringe of *Gynerium* is replaced by the somewhat smaller reed, *Arundo donax*, an occasional host of cane-borers (*Diatraea*) in Argentina and Antigua (Box). The railway is fringed with plantations of exotics, including an Australian *Acacia* and *Grevillea*. On the higher levels there is some second-growth forest, with a few fine *Cedrela*, but the country is very extensively denuded. On the further slopes some weedy cane occurs on the valley flats, in the midst of bare hills and rough pasturage. Some hills show scattered dry forest of *Bursera gummifera*, *Bombacopsis* sp. and a yellow-flowered *Agave*. Lower still, near Maracay itself, there are hedges, very reminiscent of Cuba, of *Bursera* and *Gliricidia*, and isolated trees of *Guazuma* and *Melicocca bijuga*. Better Guinea-grass pastures appear, with great shading umbrellas of samáns (*P. saman*), the same trees shading occasional belts of coffee. The hills surrounding the basin are greatly denuded, with many *Agaves* and, in places only, thin wiry pasturage. To the north they bear more *Bursera* forest, the red, leafless branches very conspicuous in the dry season.

The uncultivated portions of the flats between Maracay and Valencia are covered with *Acacia macracantha* thickets shading abundant beds of *Ipomoea crassicaulis*—a curious combination. There was also a *Cassia* (aff. *bicapsularis*), abundant and showy.

The more low-lying shores of the lake are clothed in some places with bulrushes (*Typha*), in others with wide pure stands of a gigantic *Amaranthus*, 13 to 14 feet high and 4 inches thick at the base. Other stretches of the lake shore, with sandy beaches, are backed by dense, wide shrubbery of the composite, *Tessaria mucronata*, followed landward by *Acacia macracantha* thickets, interspersed with tall *Cassia*. An influent stream, which lost its water in the sand, was bordered in its upper and wetter reaches with trees of *Hura crepitans* and *Erythrina glauca*.

On the road north, to the coast at Ocumare de la Costa, some of the leeward foothills are clothed in *Byrsonima crassifolia*-*Curatella* savannah, especially on the ridges. The upper valleys soon become filled with forest, first of a dryish type, with *Acrocomia sclerocarpa*. Some distance before the saddle (3,773 feet) is reached, one enters dense, luxuriant cloud-forest, with *Heliconia*, *Philodendron*, *Carludovica*, *Xanthosoma*, *Cyclanthus*, *Hieronyma*, *Begonia*, *Piper* spp., *Costus*, *Brodiaea*. This forest is strongly reminiscent of that clothing rather lower levels of a continuation of the same range in Trinidad.

Agricultural ecology.—The Valencia basin grows coffee, cotton, sugar-cane and maize and various forage and provision crops. There are excellent pastures of Guinea-grass, of Pará grass and of Wynne grass, *Melinis minutiflora*. Maize and cotton, either separately or as alternate rows in the same fields, perhaps form the most extensive of the scattered cultivations. Coffee cultivation has decreased ostensibly on account of repeated droughts and non-dependable seasons, but Pittier considers that the use of large shade-trees, now become gigantic, has been an important adverse factor.

One large sugar estate about 5 miles from the lake was visited, by the courtesy of General J. V. Gomez, President of the Republic, with some 600 to 700 hectares under cane. This is one of the largest estates in Venezuela, the only other extensive ones being in the Maracaibo district. It is evidently a more modern industry than in the Valley of Caracas; the chief variety is *Cristalina* but there is much BH 10 12 and some Santa Cruz and Criolla. Some ratoons have not been planted for 20 years; the average is about 10. There is no burning at all, but the soil is already too rich in potash. Cutting begins in January or February, the large and up-to-date mill handling the whole crop in a limited period. The cane cultivations are interspersed with Guinea or Para grass pastures, and occasionally planted inter-row with maize. The chief grass in the cane-field paths (traces) is *Pará* grass.

No favourite alternate hosts of *Diatraea* were found; even in wet maize fields. Near the lake the chief weed-grasses were *Cenchrus echinatus* and *Pará* grass.

Pests and associated animals.—On the cane estate visited, the management knew of no borers either in sugar-cane or in maize. There was more damage to cane by leaf-cutting ants (*Atta* sp.) than I have seen elsewhere. They were actually busy at work in daylight.

Small birds are as scarce in the cane-fields as in the Valley of Caracas. Near the lake margin they are more plentiful, especially small ground-doves, seed-finches (*Sporophila*), blackbirds (*Holquiscalus*), Tyrannids and flower-peckers (*Coereba luteola*). A small burrowing-owl (*Speotyto*) occurs in the cane-fields. On the road from Caracas, the gigantic stick-nests, often several feet long, of a *Synallaxis*, are most abundant and conspicuous objects in the wayside trees.

Ground-lizards, including a striped species of *Cnemidophorus* and an *Ameiva* are less scarce in the cane-fields than under Caracas conditions; while on the sandy lake shores they are more abundant than I have ever seen them elsewhere, save in Cuba, chiefly the *Cnemidophorus*. On the other hand not one of those important insect-eaters, the leaf-lizards (*Anolis* and related genera), was seen.

Ocumare de la Costa.

Geography.—Ocumare de la Costa (not to be confused with Ocumare Tuy) is a narrow valley opening on the north coast, on the rocky shore of the Caribbean Sea. It was visited* primarily to study Venezuelan cacao insects, but an unexpected find yielded interesting data also for the cane-borer investigation. Meteorological records are unfortunately lacking. We have seen that the heights separating this valley from the Valencia basin are clothed in extremely hygrophilous cloud-forest. From there down the Ocumare Valley, to the sea beach, is a regular sequence towards xerophytic conditions, the cocoa being grown mostly on the flats and lower slopes towards the head of the valley.

Vegetation.—The side spurs which bound the valley to the east and west are clothed in dryish deciduous forest dominated by *Bursera gummifera* and an (at this the dry season) equally leafless *Bombacopsis*. More mesophytic conditions are maintained in the valley itself by the considerable Ocumare stream and its tributaries, and there, judging by the vegetation, the rainfall must be distinctly higher than the average for the north coast. Nearer the beach the hill slopes become drier still, with tall *Cereus* and *Acacia macracantha* thorn-forest, but the bed of the valley continues wet, with fine lush pastures of *Pará* grass, and in places, high clumps of *Paspalum virgatum*† under the coconut palms. The Ocumare stream is fringed in places with *Gynerium saccharoides* and also beds of tall and luxuriant *Panicum grande*, which proved a new borer (*Diatraea*) host, being heavily infested. There was some

*Again by the great courtesy of General Gomez, through the kind offices of Dr. R. Requena and General Yañes.

† On taking specimens to the herbarium in Caracas, I was informed by Dr. Pittier that this was the first record for Venezuela!

Hymenachne auriculata, but this was not attacked. Stretches of Guinea-grass occur in the drier parts of the valley, and of *Paspalum conjugatum* under the more mesophytic conditions.

Agricultural ecology (chiefly cacao cultivations).—In the preliminary report I gave far less space to the ecology of cacao-plantations than to that of cane-fields. In view of the very great influence of the ground-cover on the incidence of such pests as thrips, as lately emphasised by Kalen (1934, p. 145), I have sought here to remedy the omission by comparing Ocumare conditions with those of cacao districts in Trinidad.

The combined cacao estates in the valley of Ocumare cover an area about 15 kilometres long by 1 to 3 wide. A very large proportion of it is under the shade of tall *Castilloa* rubber, an arrangement which seems to have been of little advantage to either crop. Much of the cacao is of pure Criollo type which still maintains itself in these isolated valleys, while elsewhere it has been largely swamped by crossing with Calabacillo brought from the east of the country (e.g., the Orinoco Delta), where this type is grown exclusively. The other chief varieties are known locally as Cundeamor (closest to Criollo), Cojorido Toro, Zambito (an intermediate type) and Blanco (cf. Pittier, 1926, p. 149). Almost all is irrigated by a great system of shallow ditches, which are filled alternately by rough sluices. Occasionally some of the ground is flooded by excess of irrigation water, so that trees are standing for a time in water, like many of the wild trees during the wet season on the Coppename River in Dutch Guiana. The contrast between the moist soil of the cacao-fields and the deep dust of the roads was very marked at the time of our visit (December). The dense shade of the tall *Castilloa* and other trees of course helps to conserve the moisture. The other shade-trees include gigantic *Erythrina* and other Leguminous trees, besides a few residual forest giants, among which was a *Ficus* with a trunk 15 feet in diameter at about 6 feet from the ground. A *Monstera* sp. is a common climber on these shade-trees, including the *Castilloa*. Trinidad cacao is shaded on the higher levels, chiefly by *Erythrina micropteryx* and on the lower by *E. glauca*. Most of the ground herbage at Ocumare consists of Dicotyledons, above all *Petiveria alliacea*, with its prickly adherent fruits and disagreeable smell. Also abundant was a *Piper* with oval, shiny leaves, and the sharply stinging nettle, *Urtica* sp. Beneath these the ground is also well-covered with dead leaves, most of the shade-trees, including the *Ficus*, being at least semi-deciduous. Bananas are grown extensively and cut for mulch (as also sometimes in Trinidad). In moister places and along ditches grew a more varied ground-flora; a red *Canna*, a white-flowered *Calathea*, a *Cyclanthus*, a few coarse ferns, a *Crinum*, a *Commelina*, and the wild rice, *Oryza latifolia*. A large gang of men is employed constantly in cutlassing this herbage, but no digging is done. Most Trinidad cacao-fields afford a great contrast to those of Ocumare in that the ground vegetation consists very largely of grasses and ferns, Dicotyledonous herbs being usually in the minority. Large *Heliconia*, especially balisier (*H. Bihai*) are often much in evidence, the latter being planted as shade for young cacao. Other common plants are *Adiantum* (maidenhair fern), *Centropogon surinamensis* (widespread), *Axonopus compressus*, *Paspalum conjugatum* (these two grasses sometimes coming in where gamalote has been scrupulously eradicated), *Paspalum nutans* and *Panicum polygonatum*. The larger ferns, with large, coarse fronds, and the soft herb, *Zebrina pendula*, are favoured as ground-cover, while the gamalote grass (*Setaria* (*Chaetochloa*) *sulcata*) which is perhaps the most frequent cacao weed, forming a thick mat of roots, is greatly disliked, great expense and labour being employed in pulling it up.* At Ocumare de la Costa I saw very little of this grass, and then in ditches, not under the cacao itself. Pruning at Ocumare seemed to me rather excessive—even more so than the usual Spanish system.

*Attempts have even been made at biological control, by colonising on other estates a smut which plays havoc with the gamalote in the wetter valleys of the Northern Range, e.g., Aripo.

Pests and associated animals.—The most noticeable pest of cacao is a small frog-hopper (*Clastoptera* sp.) probably of very little economic importance. Cocoa-beetle seemed entirely absent, nor did I find a thrips infestation. The management was of the opinion that the only important affection of cacao is "cacao macho" ("male cacao"). A tree which is or becomes "male" ceases to bear fruit and finally dies. The flowers drop off, and the shoots, instead of forming straight chupons, grow into branchy useless tufts called "palmita" (cf. Nowell, n.d., p. 175).

Birds—parrots, woodpeckers and a medium-sized Dendrocolaptid—are not uncommon in the cacao-fields. One squirrel was seen. In the open the valuable insectivorous Kiskadee, *Pitangus sulphuratus*, is very plentiful, and small birds in general are markedly in evidence, in great contrast to the Valley of Caracas. Ground-lizards (*Mabouia* and *Ameiva*) are rare in the cacao, *Cnemidophorus* very abundant in the open. A small leaf-lizard (*Anolis* sp.) is common in places on cacao, as is *Anolis chrysolepis* in similar cultivations in Trinidad.

The north coast of Venezuela from La Guaira to Carúpano.

A coastal steamer taking us from La Guaira to Trinidad, called at Guanta, Cumaná, Pampatár and Carúpano. We were able to make cursory observations at La Guaira, and at all the other ports save Cumaná.

Geography.—The important fact is that the settlements under consideration are all situated on the coast, or like Pampatár, on an offshore island (Margarita), on the very (sometimes excessively) narrow littoral between the coastal Cordillera and the waters of the Caribbean. The prevailing impression is one of aridity, decreasing, however, as one proceeds inland, and mitigated somewhat in the slightly interior valleys.

Meteorology.—The average annual rainfall for the seven years, 1920 to 1926 (Sifontes, 1928), at La Guaira was 18.7 inches, at Cumaná, 14.2 (but in 1920 not a single millimetre fell), at Carúpano, 30.4 inches. This is thus the driest region of the whole country. There is a very marked dry season from November to April or longer. The temperature along the coast, according to Pittier and Baker, averages from 78.8° to 82.4°, that is to say, it is among the hottest of the *tierra caliente*. Humboldt (trans. 1852, 3, p. 114) remarked on the high relative humidity—nearly 90 per cent.,—in the vicinity of Cumaná, which, as we have seen, is our driest station for which rainfall records are available.

Vegetation.—Rising abruptly behind La Guaira the peaks of La Silla and Naiguatá thrust their heads into the clouds. Below the cloud-belt the forest descends only a short distance, as a stunted, grey-green scrub. The lower ridges are in places denuded of vegetation and show a bare vivid pink. On the sea-front grows *Calotropis procera*, *Tribulus cistoides*, a coarse glaucous sedge, and many trees of *Coccoloba uvifera*. The environs are clothed in thorn-forest, with *Acacia farnesiana*, *A. macracantha*, *Ricinus communis*, column Cacti and *Opuntia*. Towards Puerto Caribe, east along the coast, where it is somewhat better watered, occurs some swamp-vegetation (*Phragmites*, *Eleocharis mutata* and *Acrostichum aureum*), and one cane-field.

The vicinity of Guanta is similarly dominated by thorn-forest, though mangroves skirt the water. Near the base of the hills is a little open evergreen forest with abundant leafy creepers (especially *Chamissoa altissima*), interspersed with *Acacia macracantha*, which dominates as soon as the slopes are reached. Cumaná and the very dry Araya Peninsula are bare and almost plantless. Pampatár, on Margarita Island, is backed in the distance by high hills (up to 2,670 feet) hidden in the mist. Shoreward are dunes capped with halophytic herbs, and wide sand-flats. Behind these are low reddish hills scantily covered with thorn-forest dominated by column cacti and *Opuntia* sp., with beds of a small yellowish Bromeliad and small Crotons.

Carúpano, in keeping with its higher rainfall, shows very much more mesophytic conditions, reminiscent of the drier cane-lands of Cuba and Jamaica, with *Bromelia*

pinguin, *Tecoma stans* and *Momordica charantia* as common roadside plants, the vegetation being greatly modified by cultivation.

Agricultural ecology.—The chief cultivations visible along the coast are coconut groves. At Guanta these rose from a tangle of Guinea-grass, *Bauhinia*, *Eupatorium* and other shrubs and herbs.

Cane cultivation is widespread, but patchy at Carúpano, among the low hills behind the town. The canes looked parched and, perhaps as a result, "twisted top" (not *pokkah boeng*, but the mechanical form) seemed unusually abundant.

Pests and associated animals.—There was a moderate infestation of cane-borer (*Diatraea*) at La Guaira and at Carúpano, very considerably above the average for Caracas and Valencia cane-fields, but whereas the La Guaira borers belonged to the common Venezuelan (and Colombian) form (*Diatraea busckella*), those at Carúpano were *D. saccharalis* and *D. canella*, showing an approximation to Trinidad conditions.

Small birds are by no means uncommon along the north coast. At Pampatár, mockingbirds (*Mimus gilvus*) and blackbirds (*Holoquiscalus*) were abundant in the low scrub. Ground-lizards, chiefly *Cnemidophorus*, are markedly abundant, notably along the shore at La Guaira and in the cane-fields of Carúpano.

4. The Venezuelan Llanos.

Geography.—The llanos, the most extensive stretch of savannah country in northern South America, comprise an area of about 200,000 square miles (Jones, 1930, p. 17) stretching from the Guaviare River in the south-west to the Delta of the Orinoco on the east. About a third of this region lies in Colombia, but only the Venezuelan portions have been developed or even explored.

These vast plains are entirely of Quaternary and alluvial formation, the soils varying from gravels to silts, approximately as one passes from north to south. The total absence of stones in the lower llanos was a cause of great wonder to the first Spanish explorers in 1521. The elevation is in general no more than 250–300 feet above sea-level (Humboldt, trans. 1852, 2, p. 88). The llanos are on the whole well-watered by several of the large rivers of the Orinoco system; widespread floods mark the annual rise of these streams. Some of the plains are undulating, others are of a prairie-like dead-level over vast areas.

The writer's impressions of the llanos were gained solely under dry season conditions, in a journey from Caracas to Calabozo and the Apure. Observations on the vegetation have already been published (Myers, 1933) and need only be summarised here.

Meteorology.—The temperature in the midst of the llanos shows a very marked range during the 24 hours. The most characteristic climatic feature is the very long dry season (November to March) rendered still more detrimental to vegetation by the dry north-east wind, which has left its moisture in the coastal Cordillera. The rainfall is not high, that of Calabozo being 48 inches and that of San Fernando de Apure 50 inches, but it is closely concentrated in the wet season, which is rendered still wetter by the wide inundations from the great rivers, which abruptly change the means of transport every year over vast areas from horseback to boats.

Schimper (1903, p. 277) describes the llano climate as one hostile to woodland. He says that there is a quite rainless season of five months, during the greater part of which the dry easterly trade-wind blows almost continuously and usually with extreme intensity, and is associated with great heat and dryness of air. Such a dry season, he remarks, is unfavourable to woodland but does no harm to dried-up prairie, whose existence is maintained only by the roots. And according to Humboldt it rains continuously during the wet season, thus favouring grassland, which depends on very frequent showers.

Vegetation.—Practically no ecological work has been carried out on the llanos. Consequently the present remarks must be confined to the area seen by the writer on the journey from the Valencia basin to the Apure. On this traject the plant-covering may be divided into three zones, from north to south—the approach to the llanos, the higher llanos (El Sombrero to Calabozo), and the lower llanos (Calabozo to San Fernando de Apure).

The approach to the llanos.—In the southern foot-hills of the Coastal Cordillera there has been much clearing and modification of the vegetation by man and stock. Some of the hilly open country is, however, original and typical *Andropogon-Curatella* savannah, varying from open grassland to *Curatella americana* in orchard formation. South of San Juan de los Morros one passes through large continuous areas of a low open type of forest. Some of this is definite thorn forest, with *Acacia macracantha* dominant, but the larger area, consisting of taller, then largely leafless, trees, approaches more to a monsoon type. The rainfall, of which there are unfortunately no records, can be only about 40 inches, thus falling far below that required by the monsoon forest of Schimper's definition. It agrees better with his savannah forest, to which, indeed, he actually refers it (1903, p. 353), but I consider the term very misleading, since none of the typical savannah trees or shrubs, such as *Curatella*, *Bowdichia* and *Byrsonima* are present. It would be better to follow Troup (in Tansley & Chipp, p. 292) and call this merely "deciduous forest" until a better classification has been drawn up.

A few miles south of Ortiz the country begins to flatten out, the deciduous bush becomes much lower, and interspersed with llano palms (*Copernicia tectorum*). On the higher llanos, between El Sombrero and Calabozo, there are still occasional patches of low deciduous forest, marked by the gorgeous yellow flowers of *Cochlospermum vitifolium*, but the predominant association is grassland, at first undulating but later flat, the dominant grass being *Cymbopogon rufus*, with more or less scattered small trees of *Curatella* and *Bowdichia virgilioides*. These trees are, in other places, replaced by llano palms.

On the lower llanos, between Calabozo and San Fernando de Apure, at first the *Cymbopogon* continues to dominate, but is interspersed with increasing numbers of a blue-flowered Labiate, *Hyptis suaveolens*, which becomes a co-dominant, these two plants covering extensive, dried up, dusty, treeless plains almost to the exclusion of other plants. In places and over considerable areas the whitish sea of bleached *Cymbopogon* gives place to a taller, reddish grass, *Andropogon condensatus*, still mixed with *Hyptis*. Further on the latter, probably as a result of selective grazing, grows in almost pure stands for miles. *Curatella* savannah alternates to some extent with *Cymbopogon* plains devoid of trees or bushes. Occasional dried swamps and lagoon-margins are clothed with other grasses—semi-wild rice (*Oryza sativa*), *Sacciolepis vilfoides*, *Steirachne diandra*—and other swamp-plants such as *Thalia geniculata*, *Ipomoea crassicaulis*, and in the actual water, *Cyperus articulatus* and *Eleocharis geniculata*.

The fringing forest of the main rivers and their tributaries is considered by Pittier to be typical monsoon-forest, the deficient rainfall being compensated by the soil-moisture.

Extensive stretches of comparatively close-growing llano palms appear. These are replaced in wetter areas by moriche palms (*Mauritia flexuosa*), of which, however, we met none on our traject. The grasslands so far encountered may be classified nearest the low bunch-grass savannah type of Bews (1929), though possibly their wet-season appearance might give a different impression.* To a varying distance (some miles) from the Rivers Apure and Portuguesa, however, extends a wide zone

* The non-importance of *Trachypogon plumosus* in the vegetation on our traject I can hardly believe to be characteristic of the llanos as a whole. If so, it is in striking contrast to the Rio Branco-Rupununi savannahs further south, where this is the dominant grass over vast areas.

of true *high grass savannah* marked, at least in the dry season, by an overwhelming dominance of the coarse grass, *Paspalum fasciculatum*. This high grass savannah is dependent less on annual burning—which all the llano suffers—than on the deep annual inundations. It is thus more specialised and not quite of the same origin as that characterised by Bews (1929, p. 292).

Agricultural ecology.—Cultivations are restricted to the vicinity of the isolated ranch-houses, as provision-patches and small fields of windswept bananas and, in the dry season, drought-stricken cane. Occasionally one sees irrigated plots of Guinea-grass, Pará grass or lucerne. The grazing of cattle and horses extends unrestricted by fencing, over a large area. In colonial times (Jones, 1930, p. 20) the industry was far more important than at present—a position for which political vicissitudes have been largely responsible. Thus the 4,500,000 head of cattle were reduced by 1823 to about 250,000, both stock and llaneros having been worse than decimated by the Wars of Independence, in which the horsemen of the llanos played such a stirring part. According to Jones, the remnant had again increased to 6,000,000 by 1864, reaching a maximum of 8,600,000 in 1883 and again falling off to 3,000,000 by 1924. Drought in summer and floods in winter exact always a heavy toll, and the withdrawal of the flood water is periodically accompanied by terrific epizootics which cause a special mortality among the horses.

Man has affected the original vegetation in two main ways, both consequent on the introduction of grazing animals. There can be no question that fires have been much more frequent on the llanos since the advent of man, and especially of civilised man. Paez (trans. 1929) and others mention that Mendoza advocates regular annual burning off of the coarser grasses. It may be that the great height and tangled growth of the Apure grasslands, as noticed by La Puebla in 1521, were due to a lesser incidence of fires at that date, since it seems that the height of the grass nowadays is distinctly less. The pros and cons of savannah grass-burning have been discussed in other places (Myers, 1934 b).

A change of considerably greater extent has been brought about by the grazing itself. During the dry season much of the plains are obviously overstocked. We found the wide margins of many ponds and streams eaten as smooth as a billiard table. Undoubtedly the vast areas, in the drier localities, of the aromatic Labiate, *Hyptis suaveolens*, and, in wetter places, of the convolvulaceous bush, *Ipomoea crassicaulis*, are due to selective feeding on the part of the stock, and represent a by no means negligible deterioration of the llanos as pasture.

Pests and associated animals.—In all these widespread grasslands not a sign of froghoppers was found, even in the moister areas. *Diatraea* of several species attacked the grasses of the high grass savannah near the Portuguesa and the Apure. Considerable stretches of *Malachra alceifolia* in the drier portions of the high grass zone were apparently free from the attacks of cocoa beetle (*Stirastoma*), although in Trinidad this plant is a greatly preferred host.

Birds are very greatly in evidence throughout the llanos. The physiognomic species, without which no llano landscape is complete, are the turkey buzzard (*Cathartes aura*) and the black vulture (*Catharista atrata*). Almost equally characteristic is a great cinnamon-coloured hawk, *Heterospizias meridionalis*. About every farmhouse the useful blackbirds (*Holoquiscalus*) are very abundant. Typical birds of the open llanos are the fork-tailed (*Muscivora tyrannus*) and red-breasted (*Pyrocephalus rubineus*) flycatchers, the meadow larks (*Sturnella*), the yellow finch (*Sycalis flaveola*), the thick-knee (*Oedinemus bistriatus*), the burrowing owl, and immense numbers of quail, hawks (many species), herons, spoonbills, storks, jabirus, and ibises. It is remarkable that in the high grass zone small birds are practically absent, while the useful fork-tailed flycatcher seems most abundant where the stiff woody *Hyptis* abounds, being limited elsewhere by lack of perching places. About lagoons

and wooded river-banks the numbers of small birds, large waders and water-birds, is phenomenal.

Ground-lizards of the genera *Ameiva*, *Tupinambis* and *Cnemidophorus* are comparatively abundant, especially on the drier river-banks. Large iguanas were met with even on the dry, dusty, *Hyptis*-covered plains, far from water.

5. The Delta of the Orinoco.

Geography.—The Orinoco pours out its water by some 80 or 90 mouths and caños, spread along some 200 miles (or 375 if all the eastward draining creeks are included) of coast-line, and the delta thus formed is a low-lying triangle some 12,000 square miles in area. The banks of the innumerable largely tidal creeks and caños are very ill-defined, and widely inundated, so that a large portion of the Delta, whether forested or savannah, is swampy and permanently under water. There are occasional islands of higher ground—either lateritic ridges or sandy knolls. Only the eastern section, entered over the border of British Guiana, by the Amakura (Amacuro) and Cuyuwini Rivers, was visited by the writer. The cacao-growing areas about Tucupita have not yet been investigated.

Most of this region, and of those described in the following sections (6) and (8), forms part of the Guianan Forest and Grazing Region of Jones's (1930) classification. He draws attention to the fact that this area has a population among the smallest of the agricultural regions of South America. A very large proportion of the whole has a density of less than a quarter of a person to a square mile. It is needless to stress that, for one who believes in the fruitfulness of the primitive habitat for biological control research, this region offers some of the greatest possibilities in South America. Promising preliminary discoveries have already confirmed this.

Meteorology.—The nearest recording station—Cuidad Bolivar, at the head of the Delta—receives an average annual rainfall of 36·4 inches, but this gives us no information on the Delta climate, for this station is situated in the llanos. Pittier (1926, p. 19) thinks that the rainfall certainly exceeds 60 inches, spread fairly well over the year. From British Guiana records, which show a progressive increase along the coast from east to west, and from my own experience of the Delta climate, I should estimate the annual average, at least in the eastern parts, at not less than 100 inches. The relative humidity is evidently uniformly high.

Vegetation.—By far the greater part of the Delta is covered with swamp-forest, of which two main types may be distinguished, much the more abundant being truli-swamp characterised by the dominance of the huge-leaved, short-stemmed truli (*Manicaria saccifera*). Seen from an aeroplane these magnificent palms, with their almost undivided great fronds, resemble a gigantic cabbage, and are so abundant that they touch one another for miles. The proportion of trees present in this association varies considerably. Where they are abundant the surface is a tangled maze of writhing roots, snake-like or stilted or widely buttressed. The undergrowth, where abundant, is predominantly Monocotyledon, dispersed in the genera *Rapatea*, *Heliconia* (e.g., *H. humilis*), *Calathea*, etc. The most frequent accessory palm, at times co-dominant, is manicole (*Euterpe edulis*).

The second type of swamp-forest, connected with the first by a complete series of gradations, is characterised by the absence or scarcity of palms and the predominance of small trees (e.g., *Moronobea coccinea*) with stilt-roots, and little undergrowth.

In a category by itself is mangrove forest (chiefly *Rhizophora mangle*), which fringes the coast and the creeks for a distance from the sea varying according to the size of the stream. Throughout, the bank vegetation shows a marked zonation along the course of the streams, the mangrove zone being regularly succeeded upstream by a zone in which the small tree, *Pachira aquatica*—the original host

of the cocoa-beetle (*Stirastoma*)—is dominant. Equally zoned are the beds of floating-grass, which, together with water-hyacinths (*Eichhornia crassipes* and *E. azurea*), break off and form huge floating islands, which travel up and down with the tide. Of these grasses, the chief are *Panicum elephantipes*, associated with the upper mangrove-zone, and *Paspalum repens*, in the *Pachira*-zone, both very important original hosts of the small moth-borer (*Diatraea saccharalis*), which was one of the three main objects of our visit.

Two other important plant-communities need mention. The lateritic or sandy mounds, hills and ridges which rise like islands from the low-lying country, sometimes from the very banks of the streams, at others far in between them, are clothed with rain-forest of the usual highly varied and luxuriant Guiana type, of which the best description is to be found in the work of Davis & Richards (1933-4). The undergrowth here tends to be more bushy and Dicotyledonous, but the tall Musaceous plant, *Heliconia Bihai*, is abundant, and forms the original host of the large cane-borer (*Castnia licoides*), to investigate which was our second main object. The original vegetation of the high islands has been profoundly modified by human settlement. There is scarcely one, even in the recesses of the Delta, which has not at some period been the dwelling-place of Warrau Indians, as evidenced by the second growth, sometimes so old and tall as to have reverted almost to its primitive state, sometimes so young as to consist of almost pure stands (reefs) of *Heliconia Bihai*, with an occasional *Cecropia*. Clearings still in cultivation or only just abandoned support a luxuriant covering of grasses, such as *Paspalum conjugatum*, *Syntherisma digitata*, and *Panicum pilosum*, with a small, fine-leaved *Cyperus*.

Interspersed, like the high islands, in the great extent of swamp-forest are open wet savannahs, often fifteen or more miles in diameter, covered predominantly with a large, coarse brown cutting-sedge (*Rhynchospora* sp.), and marked by groves of beautiful moriche or aeta palms (*Mauritia flexuosa*), which supply almost the sole vegetable food of the more primitive of the Warraus, who are known as "aeta Warraus" in consequence.

Agricultural ecology.—Cultivations in the sections visited are confined to Indian provision-patches, and three or four small conucos or farms planted by missions and Venezuelan settlers. The most interesting crop from our viewpoint is sugar-cane. There are two varieties, a "white" and a so-called "black," both apparently brought in long ago by the Warrau Indians. The canes grown in somewhat larger patches by the few whites are derived from the Indians in the vicinity. Sugar-cane was first planted in the Delta in 1650 by the Spanish priest Ortega (for details see Myers, 1932 b, p. 265).

Pests and associated animals.—The three main insects of agricultural importance which we hoped to study in the zone were the small cane-borers (*Diatraea*), the large borer (*Castnia*) and the frog hopper (*Tomaspis* sp.), all here present in some numbers, and their status in primitive plant-associations has been described in some detail in another publication (Myers, 1932 b). *Diatraea*, strikingly enough, was completely absent from the cane cultivations and likewise from the grasses of the wet savannahs, but was abundant in floating grasses of the forested stream margins—evidently an original habitat of *D. saccharalis*, the commonest and most important of all the economic species. In nearly 300 years it has not learned to attack cane. *Castnia* was widespread in *Heliconia Bihai* (balisier or wild plantain, so-called) of the laterite islands, more in the comparatively virgin forest than in the dense pure second-growth stands of this plant. In the former we found it attacked by a promising Tachinid parasite. *Castnia* was often very plentiful in the canes and bananas of the small cultivations.

Froghoppers, especially *Tomaspis bodkini*, a form very close indeed to the Trinidad species (*T. saccharina*), are locally abundant in the weed grasses around Indian huts and provision-grounds on the laterite risings.

The chief Arthropods causing annoyance to man are mosquitos, including numerous Anophelines, Tabanids, and *bête rouge* (*Trombicula*). I have given some account of these in another place (Myers, 1934 c).

A striking feature of both the swamp-forest and the laterite islands is the abundance of insects in great variety (beetles, ants, wasps, moths, cicadas, Membracids, etc.) attacked and fastened to forest leaves and twigs, by parasitic fungi, notably species of *Cordyceps*.

Birds, reptiles and amphibia are those of the rich and varied Guiana rain-forest fauna, the relations of which to the insects have been scarcely studied, though Beebe and his associates (1917, 1919, 1925) have made an interesting beginning.

6. British Guiana, Supplementary Notes.

Having already, in the preliminary report (pp. 34-36, 67-71), sketched the main features of the geography, climate and agricultural conditions of British Guiana, I propose in the present section to record only a few supplementary ecological observations made in the coastal belt and on a traverse of the Colony from the Brazilian border, once on foot down the Cattle-Trail and twice by boat on the Essequibo and associated rivers. Ecological notes on the forest areas of the Pakaraimas between the Rupununi and Roraima are also recorded here. Additional data on the North-West district are included in the previous section (5) on the Orinoco Delta, into which it merges: while the Rupununi savannahs are described in another section (8) with the Rio Branco campos of which they form an extension.

For purposes of comparison it may be briefly recapitulated here that 99 per cent. of the 90,000 square miles of British Guiana are undeveloped, almost the only cultivations (chiefly sugar-cane, and some rice) lying on a narrow coastal strip, while most of the remainder is heavily forested, the rainfall of the whole, always excepting the frontier savannah, varying from 80 inches (on the Berbice coast) to 150 in the interior forests, well-distributed throughout the year.

Coastal belt.—In the investigations which formed the subject of the preliminary report I had little opportunity to study the conditions of the wet savannahs behind the sugar estates, as possible reservoirs for cane-pests. This lacuna has now, through the courtesy of the Water Conservancy Commission and Mr. John Fitzgerald, been filled by several days' work at Lama Stop-off. The wet savannah here, which backs a number of the more important sugar estates and is typical of the rest, save for minor modifications consequent on the artificially regulated water-level, proved to differ in no essentials from the wet savannahs of the Orinoco Delta, and of the North-West District, mentioned in the previous section and more fully described elsewhere (Myers, 1933). No host-plants of the small borers (*Diatraea* spp.) were found, save a few odd razor-grasses (*Paspalum virgatum*) growing under entirely artificial conditions on a dam. These were lightly infested by *Diatraea canella*. No froghoppers occurred. An interesting and unexpected feature was an indication, from report and observation, that hardback beetles, which are becoming cane-pests of increasing importance, may breed in considerable numbers in the drier parts of the pegasse. This suggestion is being followed up by Mr. Cleare at a more appropriate season.

It may be taken as established that the wet savannahs of the Guiana coasts are not and probably cannot be reservoirs of infestation for *Diatraea*, *Castnia* or froghoppers. This adds to the isolation of the ecological islands formed by the Guiana cane-lands. The possibility of hardback breeding needs investigation.

The forested interior.—The ecology of the lowland forest has been the subject of a valuable study by Davis & Richards (1933-4) on the lower Essequibo, which supports a sufficiently representative number of types. The lowland virgin rain-forest is a good but difficult hunting-ground for parasites of many agricultural pest-insects. Infestations tend to be very small and localised. *Castnia* occurs wherever

its main wild host, *Heliconia Bihai*, flourishes, and it probably has other host-plants not yet discovered. Froghoppers of the *Tomaspis* type are found in considerable variety, some as true forest denizens, others only on the grasses of small artificial (Indian) or natural (e.g., river-bank) clearings. *Diatraea* is definitely rare, if not absent, over wide stretches of forest. A marked contrast to the Orinoco Delta and the Lower Amazon is the practical absence of floating grass-beds on the forest-rivers. Almost the only *Diatraea* hosts are a few local *Paspalum* spp. of clearings or river-banks. In contrast also to the Delta is the usual but slight infestation of sugar-cane in the Indian provision-grounds. The mahogany-borer (*Hypsipyla*) is widespread, but scattered, in the rain-forest trees of the genera *Carapa* and *Cedrela*. *Pachira insignis* and perhaps other species occur, but I never found on them any indication of cocoa-beetle (*Stirastoma*) attack. It seems only to occur on *Pachira aquatica*, which fringes so much of the lower river courses.

The forests of the Kanukus and associated ranges, near the Brazilian border have been studied by Davis, but I have seen no published observations. Brief notes are recorded in my paper on wild cacao and wild bananas (Myers, 1934 d). The forest at the northern base of the Kanukus is little dissimilar from mixed and more heavy lowland rain-forest. That on the higher levels is interspersed with small isolated savannahs and is characterised by abundance of a tall *Lecythis*, with cocorite palms (*Maximiliana regia*) dominating both the underbrush and the lower storeys over large areas. There are elsewhere brakes of tall *Arthrostylidium* and of a small walking-stick palm (*Geonoma*). The wild cacao grows in rocky ravines and creek-heads at a considerable elevation. The lower courses and flood-plains of some of the creeks, where they flow through the heavy forest at the base of the Kanukus, are bordered by occasionally very heavy fringes of the grasses *Tripsacum dactyloides*, *Hymenachne amplexicaulis*, *H. auriculata*, *Paspalum conjugatum* and *P. virgatum*—all either froghopper or *Diatraea* hosts, or both. On the isolated Shiriri Mountain, which rises from the open savannah, the forest is more xerophytic, largely deciduous, with rain-forest only in restricted valleys. Here *Diatraea bellifaciella* was heavily infesting the grass, *Setaria (Chaetochloa) vulpiseta*, which is also its host on Trinidad cacao-estates. The upper slopes are covered with exceedingly dense, prickly Leguminous scrub.

The more easterly route to Roraima, through the Pakaraima Mountains, up the left bank of the Ireng and past the headwaters of the Mazaruni, lies very largely in forest, varying in elevation from 500 to 3,000 feet. On this line, which is not the usual route to Roraima, but which was opened by the Boundary Commission, no ecological studies had ever been made, and the best botanical information was still that gathered by Schomburgk nearly 100 years ago. I was able to recognise, in a rather hasty march, the following main forest types:—*

i. *Deciduous forest*, below 1,000 feet (all altitudes only very approximate), in the foothills, from the southern (Rupununi) base of the range to near Iná creek. This tends to merge into rain-forest as one goes higher and further into the range. Typically, however, it is similar to the woods clothing the southern slopes of the Coastal Cordillera of Venezuela (p. 199) but is perhaps nearer to true monsoon-forest. Characteristic trees and bushes—not always associated in the same areas—are *Cochlospermum*, *Helicteres guazumaefolia*, *H. baruensis*, *Centrolobium* sp. (pau rainha), † *Bursera gummifera*, *Cedrela*, *Apeiba tipourbou*, but very often the dominant tall trees were not known to me. Over large areas in the dry season this forest is almost entirely leafless, the dry fallen yellow leaves forming a thick crackling carpet on the ground.

* The occasional interspersed savannahs will be considered in a following section (8) (p. 207).

† This is the *Ormosia histiophylla* of Richard Schomburgk's Travels (2, pp. 33, 89). It appears to be *Centrolobium paracense*, but the uniform red colour of the wood differs greatly from that ascribed to this species in the Lower Amazon by Huber.

ii. *PELTOGYNE consociation*.—Still well below 1,000 feet, this occurs on bare sandy flood-plains between Kurasabai and Karabakú, forming over limited areas one of the purest stands of one tree-species that I have seen. The tall dominants are *Peltogyne* sp., while the seedlings, the underbrush, saplings and small tree layers are practically all of this species.

iii. *Mixed rain-forest*.—Save as isolated patches and fringes in wet creek-bottoms, true rain-forest does not appear before the slopes descending to the Ichilbar Savannah. Though of various types it is not markedly different from lowland forest. Trees up to 150 feet high are abundant. This forest occurs at intervals about as far as the Ataro Falls, merging into type (vi) above 2,000 feet.

iv. *Mora forest*.—Forest in which a tall *Mora* sp. is dominant first appears as a narrow fringe in especially wide and wet creek-bottoms below 1,000 feet. At higher levels (1,300–2,000 feet) it occurs as a very pure type, very like that of Trinidad (where the dominant is *Mora excelsa*), with an abundance of mora underbrush and saplings, and *Pentaclethra filamentosa* as the most frequent subsidiary species. The taller trees reach at least 200 feet. Mora forest alternates with coppice forest (v) and mixed forest (iii) as far as the Ataro River, usually at altitudes intermediate between coppice (higher) and mixed forest (lower). Soil differences do not seem to be correlated with this distribution.

v. *Coppice forest*.—Above Ireng Falls, and at an elevation of about 2,000 feet first appears an extraordinary forest characterised by the complete dominance of a tree, which, in the absence of flowers or fruit, I ascribe provisionally to the genus *Dicymbe*. The ground is covered with its hard coriaceous leaves, shaded by its seedlings and saplings in almost pure culture. Lianes and epiphytes are rare. The tree itself shoots up eight or more large trunks from one huge base, often partly rotted and elevated on a high mound. From the base of the trunks themselves springs a regular coppice of young leafy sticks. The average height is less than that of mora. This forest type extends at altitudes of 1,500–2,000 feet as far as the Muing Creek, in the Mazaruni system.

vi. *Montane mixed rain-forest*.—This type occupies the higher ridges at intervals from above the Ireng Falls to the base of Roraima itself, at elevations of 2,000 to 4,000 feet. It is moister and usually less tall than type iii, passing in some but not all of the higher localities (above 2,500 feet) into real cloud-forest, with wet moss cushions and *Anthurium* on the ground and trunks, and an abundance of filmy ferns.

vii. "*Asheroa*" forest.—"*Asheroa*" is the Patamona name for a tall straight tree with strongly-buttressed base and large (8-10 inches long) simple very coriaceous leaves, which covers, as a strong dominant, tremendous areas of flats at altitudes varying from 1,300 to 3,000 feet, from near the source of the Ireng nearly to the Cotinga. It appears to be tolerant of altitude but never grows on slopes—only on the intervening valley flats, even slight intervening ridges being clothed in mixed forest. The wide buttresses nearly always begin as stilts—*i.e.*, the buttress is separated from the base of the trunk. In this type of forest lianes and epiphytes are abundant, the latter especially at higher levels, where the trees open out, and ground and trunks are smothered with innumerable huge *Anthurium*. The Patamonas manufacture a kind of cashiri (beer) from the just-expanding seed-leaves, which appear thickly beneath the nearly pure stands of the parent trees.

General remarks.—It will be noticed that no fewer than four of these seven types are in the nature of pure consociations of a single species—usually a rare phenomenon in tropical forests.

In types vi and vii walking is painful in the extreme, owing to the snaky tangle of roots which cover the ground to a depth of a foot and are densely screened by a thick layer of dead leaves.

From the foothills to the upper slopes of Roraima itself there has been considerable devastation from forest fires, probably dating from various drought-years. Occasionally one walked for miles through weedy second-growth of various ages, including long stretches of *Heliconia Bihai* or of bracken. At Roraima itself, the vegetation of which is now comparatively well known, the highly specialised, very moist cloud-forest which clothed the slopes between the savannahs and the base of the vertical walls (*i.e.*, to an elevation of about 7,500 feet), has been largely destroyed, at least on the accessible side, by widespread fires during one of the dry seasons between 1924 and 1926, and has been replaced by a tangle of local blackberries (*Rubus*), bracken and a small scrubby *Melastome*.*

Agricultural ecology.—Agricultural activities are as restricted as in the lowland forest, being confined to small and shifting Indian cultivations, growing the usual staple food-crops, of which by far the most important is cassava (*Manihot*). The pest situation is also that of lowland forest, but additional species of froghoppers occur. The small borer (*Diatraea*) is widespread in the Indian cane-patches, but the infestation is always negligible. It occurs in wild grasses halfway up the slopes of Roraima.

Forest types v to vii, and those parts of the others lying above 1,000 feet, are extraordinarily poor in game, all birds, mammals and fish being extremely scarce. One may walk all day through luxuriant rain-forest and neither see nor hear a single bird. This is in striking contrast to the woods of the Kanuku Mountains. The result is that the local Patamona, Serekong and Taulipang Indians are practically vegetarians, and restricted at that very largely to cassava bread and pepper (*Cap-sicum*) sauce, with neither salt nor sugar, eked out by small fish 2 to 3 inches long, caught by a hand-net, and very infrequent game.

7. Dutch Guiana, Supplementary Notes.

In the preliminary report I was able scarcely to touch cane cultivation in Dutch Guiana. This omission has now been remedied through the kindness of Mr. J. R. C. Gordon, Manager of Plantation Waterloo, who enabled us to make a few days' studies in Nickerie.

Geographical conditions are precisely similar to those of the Berbice and Corentyne cane-lands on the British side. The climate is somewhat drier, but the seasons follow the same course. The average rainfall for the 10 years, 1921 to 1930 inclusive, was 71.00 inches, with surprising variations, from 49.74 in 1920 to 110.64 in 1927.

The wet savannahs behind the cane-lands differ somewhat from any I have seen in British Guiana. They consist of extensive swamps of bulrush (*Typha angustifolia*), with curious islands of *Erythrina glauca* rising, not from higher ground, but from the sea of *Typha* itself.

Agricultural ecology.—Empoldering and draining is carried out as in British Guiana. The dams are covered largely with Pará grass, with occasional clumps of *Paspalum densum*—though razor-grasses, of which this is one, were cut out and almost eradicated on the advice of Mr. Box in 1926. There is some *Paspalum conjugatum*. Even high up on the dams are sometimes stretches of the wet-loving *Cyperus articulatus*. *Cyperus elatus* grows in or at the water's edge. A common weed among the young canes is a small, white-flowered *Passiflora*.

Further aback, new land being brought in and already partly drained consisted of *Erythrina glauca* swamp-forest, now ring-barked for clearing, and great stretches of *Cyperus articulatus*, smaller patches of a yellow *Canna* and of the huge *Amaranthus* which we first saw on the shores of Lake Valencia in Venezuela. On the dams only

* Tate (1932, p. 236) says the main fire was in April 1926, which was a notable drought-year, but the Fathers of the Benedictine Prelazia of the Rio Branco informed me that there were extensive fires before that year.

a few clumps of *Paspalum virgatum*, in addition to the *P. densum*, had survived the razor-grass campaign; but some very old abandoned fields were almost covered with these two grasses with some *Sporobolus indicus*. Banks and drier spots supported extensive thickets of *Cordia interrupta*.

With regard to water-grass hosts of *Diatraea*, in some of the canals both *Hymenachne amplexicaulis* and *Paspalum repens* occur, but much less of the latter than in British Guiana. A striking difference (shared by British Guiana) from Trinidad conditions is the apparently complete absence of *Paspalum fasciculatum*, a favourite host of *Diatraea impersonatella*, which is not a pest in Guiana, but is the most important small borer in Trinidad.

By far the chief cane-variety is D 625. About 50 of the 2,000 planted areas were in Uba cane.

Diatraea is an abundant borer (see p. 221), but *Castnia* is comparatively rare. Termite injury, all apparently secondary on *Diatraea* damage, was extensive. The large black spherical nests are dotted about the fields, and the weeding-gangs are paid to bring them in to the factory to be burned. No rat injury was seen, yet some time ago in Paramaribo whole fields were lost from this cause. The incidence of insectivorous birds and of lizards is much the same as in British Guiana.

The efficiency of the wide Corentyne River as a biological barrier is shown by the occurrence of mosaic disease in the Nickerie cane-fields, while still absent from British Guiana.

8. The Savannahs of the Brazil-British Guiana-Venezuela Boundary.

Geography.—Extensive savannahs cover the lower levels of the interior sandstone plateau. The most important are the Brazilian campos of the Rio Branco, the seat of a very old cattle industry, and the British Rupununi savannahs, extending north and south of the Kanuku Mountains. This savannah region is drained by the Uraricuera, Cotinga, Ireng and Takutu, flowing into the Rio Branco and Amazon, the Rupununi, a tributary of the Essequibo, and in addition, near Roraima, by several streams which eventually find their way to the Orinoco and the Mazaruni respectively.

The most extensive areas, and the only ones of economic importance, are the lower savannahs of the Rio Branco and the Rupununi, along the courses of the first five rivers above mentioned. The former have approximately an area of 14,000 square miles, and the latter less than half this, but they are not completely surveyed, both figures being probably very approximate.

The surface, varying from 200 (Boâ Vista) to 500 feet above sea-level, is usually undulating, very rarely dead level, and further diversified by occasional islands of forest, by the wooded river-fringes, and by mountains always in sight, whether the main ranges of the Kanukus and the Pakaraimas, or one of numerous isolated savannah ranges. The upland savannahs extend on the Brazilian side almost uninterrupted to Roraima; on the British side as open islands in the main forest-covering.

Meteorology.—At Bom Successo, which may be taken as typical of the Rupununi savannahs north of the Kanukus the rainfall for 1930 was 45.34, in 1931, 82.01, and in 1932, 53.67 inches. In 1930, which represents a more normal year, there was practically no rain (total, 0.25 inches) in October–February inclusive, and well below 2 inches each in September and March. In 1930 rain fell on 97 days, in 1931 on 135 days, and in 1932 on 126 days. At Dadanawa, on the savannahs south of the Kanukus, somewhat drier conditions prevail, the rainfall in 1930–1932 being 39.36, 59.63 and 52.10 inches respectively. At Arabopo, situated at the foot of Roraima at an elevation of about 4,200 feet, the minimum temperature during November 1932 was 55.9°F.

The climate is essentially similar to that of the llanos—a restricted season of heavy rains and a long dry season, leading to the same effects on the countryside. In the wet season large tracts (e.g., the famous Lake Amuku, site of Raleigh's Eldorado) are under water; in the summer the land is parched for long distances and even drinking water is hard to procure. The savannah vegetation is thus of climatic origin.

According to Koch-Grünberg (1917, p. 6) there is a periodicity of about 10 years in the climatic cycle. Ordinarily, at least up to the time of his visit in 1911, there is a slight rise in the otherwise falling river in the beginning of December, corresponding with a few days of rain. This rise is known in Portuguese as a *repiquete* and in Lingoa geral as *boiassu* (great snake). About every 10 years this fails. The observations of Bates (p. 148) seem to favour a 10-year period on the Upper Amazon also.

Vegetation.—Previous to our visits the main constituents of the savannah vegetation forming the basis of the grazing industry were entirely unknown. The herbarium lists of Schomburgk gave no inkling of the composition of the pasture, while the dominant grasses remained unidentified.

Over almost the whole of the lower savannahs of the Rio Branco and the Rupununi the dominant grass, for long stretches supplying 90 to 95 per cent. or even more of the ground-vegetation, is *Trachypogon plumosus* (Macusi name, wan-na), existing in three forms—a smooth green, a smooth glaucous (bloom-covered) blue-green, and a woolly form, not named as agrostological varieties. On the drier areas other common grasses are *Aristida setifolia*, *Andropogon angustatus*, *Axonopus aureus*, *Axonopus purpusii* and *Mesosetum loliiforme*.* The first three of these in places form nearly pure stands, never so extensive as those of *Trachypogon*. *Sporobolus cubensis* forms pure stands over somewhat moister stretches. Abundant non-grasses are *Paepalanthus capillaceus*, and the little sedge, *Rhynchospora barbata*. Bushes or low trees, especially *Curatella americana*, *Byrsonima crassifolia*, *B. coccolobaefolia*, the low mullein-like *B. verbascifolia*, *Bowedichia virgilioides*, *Plumeria*, *Roupala*, *Anacardium occidentale*, are rarely absent from the scene, varying from orchard formation to very open low parkland. Different woody species, notably *Centrolobium* sp. (pau rainha), *Helicteres althaeifolia* and a host of Myrtaceae, make up the bush islands, which are often fringed by a wide zone of *Paspalum anceps*.† The fringing forest of the rivers has still another composition, but is likewise bordered by the same grass, *Paspalum anceps*.

Low areas, locally called baixas, and lagoons are often marked by the presence of aeta palms (*Mauritia flexuosa*) in groves or in lines. Between the sedges of the actual water and the drier grasses of the open savannah occur the more mesophytic grasses, *Andropogon bicornis*, *Paspalum millegrana*, *P. plicatulum*, *P. densum*, and *Panicum laxum*, forming the only known savannah habitat of the cane-borers (*Diatraea* sp.) to which all these four grasses serve as hosts. They are often intermixed with numerous suffruticose herbs.

On the upland savannahs stretching north to Roraima, the dominance of *Trachypogon* is disputed at about 2,000 feet and above by *Paspalum contractum*, which forms a very sparse ground-covering. Other abundant grasses are *Echinolaena inflexa* (local), *Aristida torta*, *Thrasya petrosa*, *Sporobolus cubensis*, *Axonopus aureus* and, above 3,000 feet, *Paspalum hyalinum* and *P. pectinatum*. Associated with *Paspalum contractum* and *Trachypogon* are the Eriocaulaceae *Paepalanthus capillaceus* and the common sedge, *Lagenocarpus rigidus*.

* For statistics I am greatly indebted to Father H. Mather, S.J. (Bom Successo), Mr. Ashburner (Dadanawa) and Dr. Erieno Rossi (Roraima).

† I am greatly indebted to Dr. A. S. Hitchcock and Mrs. A. Chase for the very prompt determination of most of my grass material. All identifications have been made or checked by them.

Agricultural ecology.—Cultivations throughout the savannah region, whether those of the scattered ranches or of the Indians, are of necessity confined to the bush-islands and, to a less extent, to the fringe-forest, though small patches are established in abandoned well-manured corrals. In addition to the usual provision crops and poison-plants of the aboriginals, very good upland rice and tobacco are grown. The cattle industry of the Rio Branco was established in 1796 with 50 cattle (Robert Schomburgk, p. 123). That on the British side of the border began about the early nineties, but Schomburgk nearly 100 years ago found half-wild cattle which had wandered over from Brazil. There is so far practically no overstocking or resulting pasture-deterioration in the Rupununi, and under these conditions, since the present vegetation undoubtedly constitutes a "fire-climax" community, the present system of light burning for destroying roughage is not likely to modify the plant-covering deleteriously. On the Brazilian side there is some overstocking and pasture deterioration, but the stock, both cattle and horses, show on the whole, better breeding than ours.

Pests and associated animals.—In the wetter areas (baixas) mentioned above, the small borer (*Diatraea*), in several species, finds a habitat on the open savannah. *D. lineolata* often heavily infests maize. The canes of the small provision-patches, on the other hand, are never more than very lightly infested with *D. saccharalis* and with *Castnia*. Two species of froghopper occur in the open savannah, and a number more in the forest margin and in the provision-patches. The most interesting parasite of *Tomaspis* yet found (a Phasiine Tachinid) was in the latter habitat.

The flowering culms of the dominant grass (*Trachypogon plumosus*) are very heavily bored, usually *after* seed has ripened, by a small weevil which is attacked by a tiny Tachinid and a Braconid.

Ticks abound, especially the ear-tick (*Dermacentor nitens*)* and a cattle-tick (*Boophilus* sp.). Tabanids of various species are abundant, including one species, *Tabanus importunus*, which has been provisionally incriminated elsewhere in the transmission of the equine disease, mal de caderas, for which the capybaras, common and widespread in the savannah streams and lagoons are said to form a reservoir. Other stock-biting flies (apart from mosquitos and *Simulium*) such as *Lyperosia* and *Stomoxys* are surprisingly scarce. For data on other insects of medical and veterinary interest see the paper already mentioned (Myers, 1934 e).

The avifauna is essentially similar to that of the Venezuelan llanos. One noteworthy difference is the frequency of the large wren (*Heleodytes griseus*) about the ranch buildings, where it largely takes the place of the blackbird (*Holoquiscalus*) of the llanos, which apparently does not occur.

9. The Lower Amazon.

Geography.—Observations were made on several journeys between Pará and Manáos and up the Rio Negro-Rio Branco to the savannah country, while more extended studies were carried out in the vicinity of Pará (Vigia and the Rio Mojú) the great island of Marajó, the neighbourhood of Santarem, and the Ford rubber estates on the Rio Tapajoz.

The basin of the Amazon forms one of the greatest plains in the world, between two and two-and-a-half million square miles in area. Practically the whole region lies below 1,000 feet above the sea, and more than half below 500 feet.† The plains bordering the lower course of the Amazon have been aptly compared by Le Cointe (Vol. 1, p. 149) to a region just emerging from a great flood, with all the depressions still filled with water, and connected by numerous channels, which receive by

* I am indebted to Mr. L. D. Cleare for the identification of the ear-tick. The cattle-tick has never, I believe, been specifically determined.

† Tabatinga, at about 1,925 miles from the sea, is only 273 feet above sea-level.

ill-defined mouths the waters of the innumerable tributaries, forming a confused network of paranás, furos, igarapés and rivers.

The lower alluvial lands bordering the main channels, and flooded in great part every year, are called varzeas. The soil is a fine silt without a stone, or even much sand. The portions of the varzea relatively elevated, like dunes, are known as restingas, while the lower lands between are baixas, often the site of flooded forest, or igapó, where large trees stand during at least part of the year in many feet of water. The land which is above the highest flood level is known as terra firme, and is composed in general of older alluvial deposits in the form of red or yellow clays, mixed with a varying proportion of sand (Le Cointe). Islands great and small, temporary or permanent, but innumerable, are a constant feature. Quite near to the river in its lower courses, notably near Almeirim, Monte Alegre and Santarem, rare low hills (attaining at most 700 to 1,000 feet) capped by residual sedimentary rocks rise above the level of the plain. The annual rise of the river varies at Manáos, from 24 to 43 feet, and on the lower reaches, from 20 to 27 feet. Periodic heavier floods cause great damage.

Meteorology.—Pickles (1934) has recently summarised rainfall records of more recent date than those of Le Cointe. All other records are from the latter authority. The average annual rainfall at Pará from 1900 to 1927 was 99.28 inches, that at Manáos (1911-1919) 64.63, and at Santarem (1923 only) 62.92. At Pará it rains the whole year, more or less abundantly according to season. The wet season begins at the end of December and continues, with high points in January and April, till August—in other words the short and the long dry season of the Guiana littoral have fused into one. The drier months are September, October and November. In the savannah region of the island of Marajó (north and north-east) and on the north of the estuary generally there is a distinct dry season, almost completely rainless, of four months. Up the river, at Monte Alegre, Santarem, Obidos, even to Manáos, the two seasons remain very distinct, each lasting about six months: wet season, mid-December till mid-June, sometimes raining almost ceaselessly for a week at a time; dry season, beginning in mid-June, being often very severe. Thus Le Cointe recorded less than 0.8 of an inch of rain in Obidos during 156 consecutive days from June to November.

The mean annual temperature at Pará is 79.2°F., the monthly means varying only from 77.6° to 80.2°. The maximum temperature observed (1895-1910) was 97.9°F. and the minimum 66.6°F. At Obidos, the nearest station to Santarem, the mean annual temperature is 80.9°, the monthly means varying from 78.8° to 84.3°, and the absolute maximum and minimum being 102.6° and 66.4° respectively, thus considerably more extreme than in Pará. At Manáos the same authority gives the mean annual temperature as 80.2°, and the absolute maximum and minimum, 99.5° and 65.8°, respectively.

At Pará the average relative humidity is 88.3° per cent., with an absolute maximum and minimum of 99° and 43° respectively. At Obidos the corresponding records are 76.26°, 99° and 45° per cent. respectively, and at Manáos, 77.6°, 99° and 54°.

Vegetation.—The Amazon basin is covered with the largest extent of rain-forest in the world—in fact, if we include the contiguous forest areas of the Guianas to the Orinoco, and of the southern uplands to the campos, here is probably the most extensive wooded area in the world*—the great Hylaea of Humboldt.

The forest covering is most continuous in the State of Amazonas, save for the great savannahs (campos) of the Rio Branco (see p. 207) and those between the Madeira and the Purús. In the State of Pará the forests are interrupted more frequently, especially on the north bank, where exist the savannahs or campos geraes

* Haviland (1926, p. 197) reserves this distinction for the Siberian taiga, which covers a zone 3,600 miles long by 800 miles wide.

of unknown extent. On the south bank, at least until one reaches the comparatively unexplored south, the campos, though not infrequent, are of insignificant total area. Huber estimates that, north and south, about a quarter of the State area is under savannah.

The forest formations may be conveniently divided into (1) those of the maritime alluvium, chiefly mangroves (*Rhizophora*, *Avicennia*, *Laguncularia*, with *Pterocarpus*, *Hibiscus tiliaceus*, etc., as subsidiaries); (2) forest of the fluvial alluvium or varzea, the most characteristic plant-community of the Amazon, of which Huber distinguishes eight primitive types and a ninth induced by man (second growth or capoeiras); (3) forest of terra firme, divided into five types. The forest-communities which most concern the investigation are first, the estuary forest, the first section of (2), characterised by perennial abundance of fresh water, periodically banked up by the tides. This is among the most exuberant and characteristically tropical vegetation in the world, with abundance of wide-leaved Marantaceae, and an unparalleled abundance and luxuriance of palms, of some 20 species, especially *Mauritia flexuosa*. The second is the Lower Amazon varzea forest, distinguished by the abundance of *Bombax monguba* and *Triplaris surinamensis*, while *Spondias mombin*, *Carapa guianensis*, *Genipa americana*, *Virola surinamensis*, to mention a very few, are frequent. There are fewer main tree species and fewer palms (about six species) than in the estuarial forests on the one hand or in the Upper Amazon varzea on the other. Recent alluvium is colonised first by willows (*Salix martiana*) and *Alchornea castaneifolia*, which are later replaced by *Cecropia* spp., these in turn making way for the high forest of the climax association. Huber would place the western limits of the Lower Amazon varzea forest at about the mouth of the Trombetas. Between Obidos and Manáos, approximately, we are thus concerned with the Upper Amazon varzea forest. It is characterised by a great abundance of palms, being second in this respect only to the estuary, especially jauari (*Astrocaryum jauary*), associated with *Triplaris surinamensis*, *Calycophyllum spruceanum*, rubber (*Hevea brasiliensis*) and other relatively quick-growing species. On the more stable flats this forest develops into a higher type (matta da varzea mais alta, of Huber) marked by the abundance of the palm *Attalea excelsa* and by enormous trees such as *Ceiba pentandra*, *Cedrela* spp., *Hymenaea* spp., *Hura crepitans*.

There is thus often a distinct zonation of vegetation from the floating grass-beds (which we shall consider later) of the water, up through the willows, then the imbaulal (*Cecropia* association), through the jauari forest to the high woods.

Igapó is a local term signifying woods full of water, applied to the lower depressions of the varzea, where sedimentation and drainage are deficient, and more or less stagnant water remains standing between the tree-trunks for long periods. It is not correctly applied to forest merely temporarily inundated.

All the above types are characteristic of the rivers, like the main Amazon, with active lateral erosion and much resulting sediment—the "yellow water rivers." A different vegetation margins the rivers poor in sediment, the "black water rivers" (e.g., the Rio Negro), and the "clear water rivers" (e.g., the Tapajoz). The more stable beds of these rivers allow the growth of a more definitive and at the same time more varied vegetation, of medium-sized slower-growing trees (especially Leguminosae-Myrtaceae) with dense dark green or olivaceous foliage, fronted by a zone of very mixed bushes.

Capoeiras or areas of second-growth, in correspondence with the very small population, are of comparatively small extent. A characteristic tree is the imbauba (*Cecropia* spp.). Abandoned cultivations are speedily invaded by numerous *Solanum*, *Cassia*, *Piper*, *Sapium*, *Acalypha*. On the restingas of the Lower Amazon the aspect of the vegetation is often greatly altered by the planting of favourite food-palms, especially assai (*Euterpe oleracea*).

The last forest types with which we are concerned are those of the terra firme—those permanently beyond the reach of the highest floods. At times the higher and older varzea forests grade almost imperceptibly into them. A very rich zone is that which Huber distinguishes as the *general woods of eastern Pará*, easily accessible from the city. Characteristic trees are *Vouacapoua americana*, *Euxylophora paraensis*, *Zollernia paraensis*, *Mimusops* spp., *Eschweilera* spp. Brazil nuts (*Bertholletia*) are relatively scarce.

The only other terra firme forest investigated was that being cleared for rubber at the Ford Estates, 111 miles up the Tapajoz. This is of Huber's second type—*general woods of southern Pará State*, characterised by abundance of Brazil nuts (*Bertholletia excelsa*) and caucho rubber (*Castilloa*), though the latter was not seen by us on the Tapajoz. This is tall rain-forest of very mixed composition, with a great abundance of large trees. An *Attalea* is the dominant palm at Fordlandia, with some *Euterpe oleracea* and *Iriartea exorrhiza*. *Carapa guianensis*, *Tabebuia* sp., *Jacaranda copaia*, Brazil nut (*Bertholletia excelsa*), *Astronium lecontei*, *Cedrela*, *Simaruba amara* and *Mimusops huberi* are the most important timber trees.

More important for our purposes than any of the forest associations were the grass communities, represented in the investigation by the campos of Marajó and of Santarem, and by the floating and riparian grass-beds of the Amazon itself. These plant formations have been very little investigated by ecologists, but are of paramount importance as the habitat of numerous froghoppers and cane-borers (*Diatraea*).

Through the courtesy of Senhor L. Bieder we were able to study typical ranch conditions on the Soure River, of Marajó. Mangroves form the dominant bank vegetation, varied upstream by *Euterpe-Carapa* forest, frequently succeeded inland by a zone of the grasses, *Paspalum virgatum* and *Andropogon bicornis*. The campos are divided by elevation into baixos and altos (low and high), the former lying under several feet of water in the wet season. They are characterised by very different vegetation, the dominant grass on the lower savannahs being *Panicum laxum*, and on the higher, *Trachypogon plumosus*. Other grasses of the lower campos include *Paspalum densum* and *P. pleostachyum*, with many sedges (*Cyperus articulatus*, *Eleocharis geniculata* and *E. mutata*) and *Thalia geniculata* in the wetter parts, a few plants of *Ipomoea crassicaulis* and occasional isolated trees such as *Byrsonima crassifolia*. The higher campos bear scattered trees of *Curatella americana*. Both types of campos may, however, be clear of bushes and trees for miles, or even to the horizon, or, on the other hand diversified with bush islands, containing numerous palms, especially *Astrocaryum jauari*, an *Acrocomia*, and a *Desmoncus*. Common island trees are *Inga* spp. and *Carapa guianensis*, with *Ravenala guianensis* in all the larger patches. These bush islands are usually fringed by *Paspalum virgatum*, here taking the place of *P. anceps* of the Rupununi.

Nearer the sea the lower campos are covered very largely with *Sporobolus virginicus*, with patches of *Paspalum pleostachyum* on slightly higher ground.

The Santarem savannahs are mostly of the closed type, with frequent small trees, and numerous scattered clumps of diverse bushes—*Anacardium occidentale*, *Curatella americana*, *Byrsonima* spp., *Plumeria*, *Davila redula* (for a fuller list see Spruce, 1, pp. 108 ff.).

There are occasional fairly large open spaces covered with low grasses and Eriocaulaceae, especially, among the former, *Paspalum carinatum* with clumps or even extensive stands of *Trachypogon plumosus*, and, in the shade of the low trees, a stout, pale green sedge. Termite mounds up to 4 feet high are widely scattered. The soil is a loose sand or a thin layer of this overlying hard compact silt.

The riparian and floating grass-beds vary tremendously in extent and composition in different parts of the river, and are both much more plentiful on the main Amazon

than on either the clear Tapajoz or the black Rio Negro. In the neighbourhood of Pará and in the estuary only small and infrequent grass-beds are encountered. About the Furo de Breves, the first beds of water hyacinths (*Eichhornia* spp.) appear, and about Almeirim the first *Paspalum repens*. This, known locally as perimenbéca, in association with large and stout *Echinochloa polystachya* (canarana), begins to form huge floating meadows and fringes which reach their maximum development about Santarem, and provided our chief collecting-grounds for the Amazon fly. They are frequently backed on drier land by a wide zone of tall mory (*Paspalum fasciculatum*) like that of the Venezuelan llanos.

At Fordlandia, on the Tapajoz, the same *Paspalum repens*, growing much less luxuriantly, with another grass not yet determined, composes similar but less extensive beds and fringes.

Large areas of smooth mud, exposed by the falling waters, whether on the river margins or in the beds of drying lagoons, become speedily covered with the fresh green shoots of *Luziola spruceana*, growing in pure stands for miles, and aptly compared by Le Cointe to fields of young wheat.

On the lower Rio Negro and along the Rio Branco, beds of aquatic grasses are almost absent, save for a few stretches of *Luziola* in sheltered bays, and the zone of mory is also less developed.

Agricultural ecology.—There are practically no extensive cultivations in the vicinity of Pará, but the forest has been considerably modified by the shifting cultivation of provision-patches, by charcoal-burning and timber-cutting. There are long stretches of second-growth. Common roadside grasses are *Paspalum conjugatum*, *P. plicatulum*, and, in drier sections, *Sporobolus indicus*, with rare clumps of *Paspalum densum* and *P. virgatum*. Besides the artificial clearings, there are a few small natural campos very like the Aripo and Mausica savannahs of Trinidad, with *Curatella americana*, a wide-leaved *Scleria*, *Lagenocarpus* sp., *Dichromena ciliata*, *Amasonia erecta*, *Heliconia psittacorum*, *Borreria* spp., *Polygala* spp., and numerous Eriocaulaceae.

From the vicinity of Pará to the mouth of the Catrimani on the Rio Branco at about 1° N. latitude, the space about riverside houses and the margins of settlements is often thickly covered with clumps of *Paspalum virgatum*, which is apparently never a constituent of the virgin bank fringe.

Igarapé-mirim is the centre of an important sugar industry. There the muddy water-channels are dotted with small mills,* mostly making spirit—cachaça—their canes being brought to them in dugout canoes from the riverside fields, where the cane, often heavily infested in the leaf-axils with small crabs, grows on the mud among *Montrichardia* and other water-plants and some wild rice (*Oryza latifolia*) and with no rows and no cultivation. Grey mealy-bugs (*Pseudococcus boninsis*), assiduously attended by ants, are unusually plentiful, borers (*Castnia* and *Diatraea*) very rare.

The two chief cane varieties, known as cana rosa or Cavengie and cana branca or Cuba, seemed to me to be identical with the two forms in the Orinoco Delta and in Indian cultivations generally. The cana branca is preferred and is in the majority. I saw a little of a striped cane which would be called cinta in Cuba. Cane is planted at the same time that it is cut, the top being stuck into the mud. This is done twice to four times according to the quality of the land, which is then abandoned to bush. Only virgin forest land is taken in for new plantings.

Cacao occurs only in small patches or isolated trees in the vicinity of Pará and of Igarapé-mirim. Sometimes it grew under the shade of the original forest, somewhat cleared of underbush, at other times in the open among sugar-cane. It was examined carefully for cocoa-beetle (*Stirastoma*) and thrips, entirely without success, probably

* A larger mill was making white sugar, for consumption in Para.

owing to the uniformly high and well-distributed rainfall. Witchbroom (*Marasmius perniciosus*), however, was plentiful in the latter district. Cacao was examined also near Antonio Lemos, where traces of cocoa-beetle work were seen, but no thrips; much larger areas of old-established plantations, much neglected since the abolition of slavery, extend along the banks of the Amazon, especially between Monte Alegre and Manáos. Our steamer stopped at one of these, between Parintins and Uru-curituba, and while I worked on *Diatraea* in the riverside grasses, Mr. Vesey-Fitzgerald examined the cacao and reported it heavily infested with witchbroom, of which he showed me a specimen. The stout grass, *Echinochloa polystachya* (canarana) which forms such a large part of the floating islands, is regularly cut and brought for sale to the settlements, for stock-feed. The equally common mory (*Paspalum fasciculatum*) growing on the higher banks is apparently unpalatable.

The extensive cultivations of rubber and other crops at the Ford Estates of the River Tapajoz have been described in another place (Myers, 1934 c), and need not be further mentioned here, save to indicate something of the weed-flora. In the settlement itself there is much scattered luxuriant Johnson grass (*Sorghum halepense*), much *Valota insularis*, Bermuda grass (*Cynodon dactylon*) and a *Syntherisma*. Damp hollows are covered with *Paspalum conjugatum* and *P. paniculatum* (?); the former occurring also in patches along the logging paths through the rain-forest, where also is *Paspalum virgatum*, in rare clumps.

The Marajó campos are the seat of an extensive ranching industry, established in 1692 (see Myers, 1934 b).

Pests and associated animals.—I have already remarked on p. 187, that so far as sugar-cane is concerned the usual relation between the monoculture and the extent of wild host-plants is reversed on the Amazon, since the area of aquatic grasses which are favourite hosts of *Diatraea* is immensely greater than that of all the cane-lands. In accordance with the fairly general principle that large areas of one host are usually more attacked than small scattered areas—a principle which usually works in favour of peasant cultivations as against estates—the cane is very little attacked by insect pests, notably little by the borers (*Castnia* and *Diatraea*), while the aquatic and riparian grasses are often heavily infested. At Fordlandia, for instance, considerable areas of the water grass-beds were browned and practically killed by an immense mealybug (*Pseudococcus*) infestation in the terminal shoots.

Cacao is apparently free from thrips and largely so from cocoa-beetle, of which specimens were obtained on *Bombax monguba*, and traces of adult biting on isolated cacao.

Ticks and Tabanids, which are alleged to carry mal de caderas, are abundant on the Marajó campos, but horn-flies (*Lyperosia*) are apparently absent.

The incidence of insectivorous birds is strikingly correlated with the type of vegetation. Both large and small birds are abundant on the Marajó campos, as on the llanos. The Tyrannid (*Taenioptera velata*) and the big gregarious cuckoo (*Guira guira*) were seen only there. In the great palm forests of the estuary birds are exceedingly little in evidence, while in the lower Amazon varzea forest, on the contrary, they are seen abundantly from the deck of the steamer, whence as many as 50 species may be identified in a day.

Cane near Igarapé-mirim was in places attacked by a large rodent, which I did not see.

Newer clearings in rain-forest, e.g., at Fordlandia on the Tapajoz, tend to be infested by incredible numbers of the fire-ant, *Solenopsis saevissima*, attending mealy-bugs and other Coccids in the cultivations, and making walking a misery. At first they invade the houses, but are later replaced there by other, more usual house-ants. I was even told of one species of the latter, of which examples were unfortunately not obtainable, which was imported from one part of Amazonia to

another to control *Solenopsis*, but I could obtain no exact details. There is, certainly, a definite succession of dominant ants in forest clearings, and a *Solenopsis* represents perhaps the second stage in this succession, replacing the true forest ants. Bates recorded long ago (ed. 1892, pp. 222, 224, 227) severe infestations of the fire-ant on the Rio Tapajoz, and stated that one considerable settlement was for some time completely abandoned on account of their attacks.

10. The Santa Marta District of Colombia.

Lest the title of this section be regarded as too inclusive, it should be emphasised that it covers only the immediate vicinity of the town, investigated twice during the loading of the Jamaica steamer. Time did not allow a visit to the irrigated banana districts, and only sugar-cane and the general vegetation were studied.

Judging from the xerophytic vegetation the rainfall must be even less than the 35 inches which Jones (1929, p. 408) records as the minimum in the northern parts of the irrigated banana region behind it. The plain and the lower inland hills greatly resemble the drier parts of Haiti and Jamaica. The chief vegetation is *Acacia macracantha* thorn-forest with two species of tall column-cacti. A *Bombax* with greatly swollen trunk appears on the hill slopes, while the streams in the deeper inland valleys are fringed with a more mesophytic vegetation, including cocorite palms (*Maximiliana regia*), *Inga* and huge trees of *Anacardium giganteum*. There is very little grass, and no likely alternate hosts of cane-borer (*Diatraea*) save a little *Valota insularis* growing in irrigated pasture among Guinea-grass.

Two small cane-fields were visited with sparse, weedy-looking whitish cane feebly irrigated. One field contained three-quarters-grown canes and the other very young ratoons—too young yet for *Diatraea*. *Diatraea busckella* was abundant in the tall cane—much more so than at La Guaira, where likewise, this was the only borer species.

11. The Colón District of Panama.

This section includes still more fleeting impressions than the preceding one, again with sugar-cane as the chief objective.

The rainfall on the Atlantic coast of the Canal Zone is 130 inches, well-distributed throughout the year. Fogs and clouds are characteristic features of the Atlantic slopes, contrasting with the dry conditions of the Pacific side.

The lower lands on the way to Gatun are largely in moist rain-forest second-growth (*Heliconia*, *Calathea*, *Anacardium giganteum*, and pink-flowered *Tabebuia* and *Gustavia*) with open spaces over-run with introduced Guinea-grass and elephant-grass (*Pennisetum purpureum*) or great roadside beds of *Paspalum fasciculatum*, very reminiscent of Trinidad.

Sugar-cane.—A search in sugar-cane exposed for sale in the Colón shops showed very few borer-holes—perhaps 2 per cent. of the joints, and no live larvae—but then such canes are probably selected, though the infestation must be low to enable nearly all the canes brought in to be free. A small backyard patch of straggling cane seemed entirely free from insect pests. The canes looked very like Cristalina (= White Transparent). At Gatun a small infestation of *Diatraea busckella* was finally found in remarkably thick and numerous roadside clumps of razor-grass (*Paspalum virgatum*). Some parasitised material was found.

12. Puerto Rico.

When I wrote the preliminary report I had merely passed through Porto Rico *en route* to Cuba. A later opportunity was taken to examine Puerto Rican cane-field conditions, especially in conjunction with the collection of egg-parasites for the cane-root-borer (*Diaprepes*).

The distribution of ascertained and probable borer and other hosts was noticed during a journey (in June 1931) round the island, proceeding westward from San Juan. Under the moist conditions of the north coast, there are many roadside clumps of *Paspalum virgatum*, with Guinea-grass and Pará grass growing equally luxuriantly. About Central Constancia the commonest cane-field weed is Pará grass. At Rio de la Plata is a patch of *Arundo donax*. A common roadside tree is *Montezumia speciosissima* which Loftin found to be infested with pink bollworm. Clumps of *Paspalum millegrana* (with some *P. secans*) are abundant between Rio de la Plata and San Vicente. Between Vega Baja and Manati there is much luxuriant *Valota insularis*, which becomes increasingly abundant under drier conditions in the cotton country further west. Just before Arecibo are almost continuous roadside stretches of *P. millegrana*, later followed by *Valota insularis* and *Sporobolus indicus*. A small river is fringed with *Gynierum saccharoides*, and there are whole fields of *S. indicus* interspersed with patches of *Valota*. At Isabela, grape-fruit was swarming with adults of *Diaprepes abbreviatus*. Many bananas were defoliated by *Lachnosterna* (2nd June).

On the west coast to Mayaguez, and thence to Aguirre on the south, conditions are drier and fewer grass-hosts were observed. At Aguirre, the irrigation probably accounts for the prevailing Guazuma-Guinea-grass vegetation, much more mesophytic than the low rainfall warrants. All cane is grown under irrigation. *Leucaena glauca* and *Ruellia tuberosa* are common roadside weeds. The chief cane is BH 10/12. Trash is always burned before ploughing, but in ratoons is piled on the cane rows. Only one ratoon is grown. Common cane-field and cane-path weeds are *Valota insularis*, *Argemone mexicana*, *Kallstroemia maxima*, *Leonotis nepetaefolia*, *Chloris* sp., *Parthenium hysterophorus*, *Portulaca oleracea*, *Stachytarpheta jamaicensis*, *Amaranthus* sp., *Calotropis procera*.

East of Aguirre, at Arroyo, there is a line of *Paspalum millegrana* alongside the canes, otherwise only one clump seen between here and Aguirre. At Maunabo the same grass is abundant on roadside and field edges, with very luxuriant *Valota*, both extending nearly to the top of the ridge approaching Yabacoa; the top of the ridge was moister, with *Syntherisma sanguinalis*, *Paspalum conjugatum*, *Sporobolus indicus* and many clumps of *Paspalum virgatum*. On the hills beyond Yabacoa are much *P. millegrana* and *S. indicus*, with *P. virgatum* in creek-beds, and later and lower, fringing the road almost continuously.

To Ceiba and Fajardo, *Valota* is abundant on roadsides, later replaced by *P. millegrana* and *P. virgatum*, while *P. millegrana* clumps are frequent in the luxuriant *S. indicus* pastures.

With moister conditions still, past Naguabo, the road and the cane-fields are bordered with masses of *P. virgatum* and *P. millegrana*, with much *Valota* and Pará grass in places. The two former grasses continue thereon abundant at intervals till San Juan is reached.

The alternate host situation thus briefly surveyed, is an epitome of the varied conditions prevailing from the moistest parts of Guiana (save the canals) to the driest parts of Haiti or Antigua.

Tiaris omissa and *Crotophaga ani* are common birds in the south-coast cane-fields, and other insectivorous birds are not uncommon. Blackbirds (*Holotrisacus brachypterus*) are often very abundant along the roads.

The pest situation is amply described in Wolcott's very useful work (1933), which deals chiefly with Puerto Rico. Leonard has published a valuable annotated bibliography (1933).

13. The Bahama Islands.

A little over a month was spent in New Providence during April-May, 1932, for the purpose of investigating the sandfly (*Culicoides furens*) pest and advising

Government on its control. A report of this study is published elsewhere (Myers, 1934 f). It involved first a rather thorough entomo-ecological survey of the island, some results of which, together with spare-time studies of the main agricultural pests, form a part of the present investigation.

Geography.—The area of New Providence is 58 square miles and the population 12,975 (in 1930). I mention the latter figure advisedly, since the population is so concentrated in Nassau, in attendance on the tourist industry, that there are surprisingly large uninhabited tracts. There are no mountains and few hills (highest about 100 feet), but the surface is generally rocky, with swampy pockets and magnificent sand-beaches. There are no freshwater streams. The rocks are wholly aeolian limestone, with sink-holes, and outcrops of dog-tooth formation (Britton & Millspaugh).

Meteorology.—The average rainfall for the 10 years 1922 to 1931 inclusive, as recorded at the Nassau station, was 45.50 inches. For the year 1931, the mean maximum temperature was 82.57°, and the mean minimum 70.77°F. The corresponding means for relative humidity were 81.16 per cent. and 80.33 per cent. The climate is thus more tropical, probably owing to the proximity of the Gulf Stream, than its latitude, two degrees outside the tropics, would lead one to expect.

Vegetation.—Domin (1929, p. 18) depending largely on the work of Coker, distinguishes six plant-communities which he calls formations. These are (1) the sand-strand formation, which is divided into five associations, none of which concern us much here; (2) the freshwater marsh formation; (3) the important pine-barren formation, which in its lower sections consists very largely of *Pinus caribaea* with an undergrowth of palmetto, replaced in the higher lands by another palm (*Coccothrinax argentea*) accompanied by a great variety of other woody plants; (4) the coppice formation, divided into high (maximum, 35 feet) and low (maximum 15 feet), a dryish type of mixed woodland; (5) the salt-marsh formation, in which the important mangrove swamps should be included, but are not mentioned; and, finally, (6) the rocky shore formation.

Agricultural ecology.—Attempts at cultivation, in which the ubiquitous rock outcrops render the use of a plough impracticable, seem to be concentrated on areas of the coppice formation, which is cleared for the purpose. Sisal was once the most important crop, later followed by tomatoes. A promising citrus industry was ruined by Florida competition and by the introduction of the blackfly (*Aleurocanthus woglumi*), here called the blue-grey fly. This pest is now being cleared out by the Malayan wasp-parasite (*Eretmocerus serius*) introduced from Cuba by the American entomologist, Mr. Berry, on the 24th October 1931.

In a small citrus plantation at Foxhill I saw no trace of blackfly or of green scale (*Coccus viridis*), but in other places, though local, both are sometimes very injurious. The cottony cushion scale had been in New Providence about three years at the time of my visit, probably introduced from Florida, with the exotics (especially *Casuarina*) which were imported in great numbers. The Board of Agriculture was introducing the ladybird, *Cryptolaemus montrouzieri*, against mealybugs in general (*Pseudococcus* spp.).

Second-growth bush among the cultivations is often dominated by *Leucaena glauca*, so abundant in St. Kitts. Some of the tiny pockets of soil among the rocks are only large enough to hold one maize plant. Better maize fields were seen near the shore, on pure sand fertilised with seaweed. This showed considerable leaf-injury by *Laphygma frugiperda*, and a rather small infestation of borer (*Diatraea lincolata*). In the dried up and weedy-looking sugar-cane in a number of rocky fields, the common borer (*Diatraea saccharalis*) was extremely rare, if not absent. I found only two bored shoots, showing the characteristic transverse tunnels of this species, unfortunately abandoned. The pink mealy-bug (*Trionymus sacchari*) attended by two species of ants was, on the other hand, very abundant.

Cotton cultivation, according to Bacon (1927) began in the Bahamas before the American revolution. "On Long Island alone there were more than four hundred slaves working on four thousand acres. Two year's visitation of a red bug [undoubtedly *Dysdercus*, cotton-stainer] not only killed the cotton but the resolution of the planters; as the black fly in more recent years was permitted to terminate Nassau's unsurpassed citrus output."

The prevailing scarcity of small birds has been attributed to the recent hurricanes.

14. Brief Observations in Florida.

I owe to Dr. David Fairchild, Plant-Explorer to the U.S. Department of Agriculture, the opportunity, during a very few days spent in Florida, *en route* to the Bahamas, of making a few observations, especially with regard to sugar-cane cultivation, which have some bearing on the present investigation.

Vegetation.—I was greatly struck by the resemblance between much of the Everglades vegetation and certain types frequent in the Greater Antilles and on the mainland. Some of the hammocks (which we should call bush-islands on the Guiana savannahs) greatly resemble the drier type of Cuban forest which often grows on the much eroded *diente perro* limestones. There are, for instance, *Bursera gummifera* and a fine strangling fig (in this case *Ficus aurea*), but the numerous evergreen oaks strike an unfamiliar note.

The Everglades greatly resemble the wetter parts of the Venezuelan llanos, and to a less extent (being more level) the Guiana-Rio Branco savannahs. The *Taxodium* swamps greatly resembles parts of the wet savannahs of the Guiana coast, where, however, the dominant tree is the broad-leaved, so-called "white cedar," *Tecoma longipes*. The occasional edaphic pine-crests (*Pinus caribaea*) are like nothing in the south, though of course frequently met with in the Bahamas, as likewise is the widespread palmetto undergrowth.

Coconut cultivation.—On a sandy island estate off the coast at Miami, I was enabled, by the courtesy of Mr. Matheson, to see a large area of the finest and healthiest coconut palms I have ever seen, either in the American tropics or in Ceylon. The butts of many of the young trees were colossal. Most of the pests and diseases of further south were apparently absent. There were a few *Rhynchophorus palmarum*, of which I saw bred specimens, but they were too few to rank as a pest.

Sugar-cane cultivation.—With Dr. Fairchild, and at the invitation of the Director, Dr. R. V. Allison, I visited the State Everglades Experiment Station, at Belle Glade, Lake Okeechobee. The cane agronomist, Dr. Stevens, as a result of Louisiana experience that "stubble" (*i.e.*, ratoons) shows a higher sucrose rate than plant cane, proposes to convert all canes into ratoons by planting in July (instead of October), and cutting when there is one joint above the ground, spreading trash between the rows. He thinks this would help borer control (*Diatraea saccharalis*) by attracting them to the young growth which is cut above. I told him that plant canes are usually more infested than ratoons, which has a bearing on his borer-theory, but which he did not know.

On the wide shores of the same lake I saw cane estates of 6,300 and 7,000 acres respectively, planted on drained Everglades muck (peat). The yield on their good land is 60 to 70 tons an acre. The labour is predominantly negro, but a cane harvester is used. This disturbs the borer infestation counts since it cuts the canes into short, 8-inch pieces, making correlation with joints impossible. The Experiment Station entomologist therefore proposed to substitute a routine examination of stripped stools.

I saw 128 acres of Coimbatore canes (ratoons) eaten to the ground by a species of cutworm I did not recognise.

The chief cane varieties are P.O.J. 2725 and 2714 ; 2878 is being tried. Large areas of Co 281 are grown, but this variety is to be given up, as its thin stalks make it very expensive to harvest.

Fertilisers and drainage are the chief limiting factors in production. Frosts are not frequent ; in the previous winter (1931-1932) there had been only one at the Experiment Station.

At Canal Point I was particularly anxious to see the giant New Guinea varieties planted at Dr. E. W. Brandes' Federal Cane Variety Station at Canal Point, but they were too young to show up distinctly. I feel very strongly that if our neotropical Tachinids, notably *Lixophaga* and the Amazon fly, do not bring about permanent control of the borer (*Diatraea* spp.) the greatest promise will lie in New Guinea parasites which attack the related borers (at present included in the same genus, *Diatraea*) in these thick wild canes, and for which thickness of stalks will be no obstacle to parasitism.

Mahogany-borer (*Hypsipyla*).—The Florida excursion yielded a new and very promising parasite of the mahogany borer, which is described below (p. 242).

V. OBSERVATIONS ON PARTICULAR INSECT PESTS.

It is unfortunate that, owing to the difficulty of taxonomic work in the Muscoids and parasitic Hymenoptera, several of the new parasites recorded below are not yet identified. This applies especially, of course, to those which were not successfully reared, but also to some adults.

1. Sugar-cane Pests.

The ecological conditions of the cane-lands visited have been described incidentally in the appropriate parts of section IV (p. 189).

Insect-eating amphibia, lizards and birds.—A few observations on insect-eating lizards, amphibia and birds may be added here. The relative frequency of some of these predators in the cane-fields of the regions visited is indicated approximately in the table on p. 220 (confined to those regions where considerable work was done in estate cane-fields, since small and scattered cane-patches are obviously not comparable).

Bamboo bird-perches are still set up in some fields in Trinidad and British Guiana, and Mr. Pickles has planned experiments to ascertain their value in the control of froghopper and borers.

In Trinidad the ground-lizard (*Ameiva atrigularis*) is still common in mora and mixed rain-forest, where it apparently has the fewest enemies. It still occurs in the vicinity of houses, where it is probably to some degree protected from the mongoose, but is assiduously hunted by cats (two more instances since the one recorded in my preliminary report—1931, p. 24). In the cane-fields, presumably owing to the inroads of the mongoose, it has almost disappeared.

With regard to Amphibia, the giant toad (*Bufo marinus*, Preliminary Report, p. 25) is now particularly abundant in Puerto Rico, where its food habits have been very carefully investigated (Dexter, Leonard), and whence it has been introduced into Hawaii (by Dr. Pemberton in 1932). It has been shown in Puerto Rico to feed very extensively on hardbacks and on sugar-cane root-weevils (*Diaprepes*).

In Trinidad, Vesey-Fitzgerald has made interesting observations on the cane-field leaf-dwelling frogs of which he lists (1933, p. 211) four species, which feed on froghoppers. Frogs of this type are more abundant in Trinidad cane-fields than in any others investigated.

Cane-fields	Insectivorous birds	Leaf-lizards	Ground-lizards
Dutch Guiana (Nickerie)	Common**	No observations	Fairly numerous
* British Guiana	Common	Common	Common
* Trinidad	Fairly numerous	Rare	Very scarce
* Barbados	Unusually abundant	No observations	Extinct
Montserrat	Scarce	No observations	Extinct
* St. Lucia	Abundant	No observations	None seen in cane-fields
* Antigua	Fairly numerous	Very abundant	None
* St. Kitts	Exceedingly rare	Abundant	None
* Santo Domingo	No observations	No observations	Abundant
Haiti	Fairly numerous	Exceedingly abundant	Not uncommon (reported rare in Prel. Rept. p. 80)
* Puerto Rico	Fairly numerous	No observations	Fairly numerous
Cuba	Scarce	Exceedingly abundant	Abundant
* Jamaica	Scarce	Abundant	Scarce
Valley of Caracas	Scarce	Apparently absent	Scarce
Maracay	Scarce	Apparently absent	Not uncommon

* Mongoose has been introduced. It has also been imported into Cuba, but is not present in the areas where my observations were made. I saw no sign of it in Haiti.

** The order of frequency implied by these terms is as follows :—abundant, common, fairly numerous, not uncommon, scarce.

Effect of abnormal floods.—Flooding of cane-fields has long been practised in British Guiana as a measure for the control of *Castnia*, and latterly as an operation agronomically beneficial in itself. Hardbacks (SCARABAEIDAE) may also be destroyed by this practice, which, however, as Cleare has shown, is apt to leave the fields in a condition highly favourable for re-infestation. Other pests are apparently not significantly affected by this shallow and more or less temporary flooding.

The disastrous floods of the beginning of 1934 on all the coastlands of British Guiana offered an opportunity of gauging the effect of deep and wholesale flooding. Very heavy rains, totalling 11 inches in Georgetown in the first 6 days of January, were followed by a heavy storm on the 7th, when 7 inches fell in one night in the town, and up to 12 inches in the country districts. Cane estates were very generally and very deeply flooded. One estate was so badly affected that total abandonment was almost decided on. Mr. Cleare and I made a survey on this estate on 6th March of the effect on cane-pests. Incidentally the plantation in question was said to be generally the most heavily infested with *Castnia*. The cultivations were under water so long that half of them were ruined, and would have to be replanted. The floods rose to 3 feet the first day (early in January) and to 4 feet the succeeding 5 days, remaining for about 4 weeks. All canes, whether plants or ratoons, below a certain height were drowned. Probably the submergence of the growing point was the deciding factor. Taller canes kept pace with the rising water by putting out roots at

the nodes, successively at higher levels. The mature cane was being milled but was in very poor condition, owing to the mass of rootlets, milling 19 tons to the ton of sugar! In general Dicotyledonous weeds were killed out and Monocotyledons unaffected, Dicotyledonous creepers such as *Momordica* forming an exception to the first. In addition, *Montrichardia* (mukka-mukka) had come in as a new weed, widespread over the fields.

We were taken to the section which had been worst-infested with *Castnia licoides*—the most low-lying part—which was thus also the deepest and longest submerged. We examined first some growing tall cane, with no success, save old bores. We then proceeded to a pair of similar fields, one of which was being and the other had just been cut. In the latter practically all the stools were dead, save on the dams, which were under water of course to a lesser depth, about 1 foot, and for only 10 days, while the field itself was submerged 4 feet for 4 weeks. From these two fields, in early November 1933, no fewer than 3,222 *Castnia* larvae had been collected by the borer gang in 6 days. We found no survivors in these fields—only dead material and empty bores. Nor were there any in the tall live canes. All the evidence points to the practically complete annihilation of *Castnia*, at least on the lower-lying and originally worst-infested section of the estate. Re-infestation is likely to be rapid, however, since some of the high dams are planted extensively in plantains, and clothed elsewhere with beds of *Heliconia psittacorum*, both alternate food-plants of *Castnia*.

As might be expected, *Diatraea* was less affected. We found *D. saccharalis* both in shoots and in hard mature cane. No *D. canella* was found, and an interesting discovery on a dam was a clump of *Paspalum virgatum*, a favourite host of *D. canella*, bored not by that species but by *D. saccharalis*, which under other conditions hardly ever attacks it. Perhaps the floods had driven it to this unaccustomed food-plant. It seemed that the numbers of *D. canella*, which, as I have shown is much less moisture-demanding and much more easily drowned than *D. saccharalis* (cf. Prel. Rept., p. 85, foot-note), might have been considerably reduced. However, Mr. Cleare, who visited the estate again later (*in litt.* 19th May 1934) wrote that in the plant canes "there is plenty of *Diatraea*, both *saccharalis* and *canella*, so that the floods can have had little effect on them."

(a) Sugar-cane Moth-borers (*Diatraea* spp.).

Following the plan of the preliminary report, which should be used in conjunction with the present one, since no data are repeated herein, the borer infestation is studied below, region by region, with reference mainly to its intensity in cultivated and wild-host plants, and to its natural enemies. Whereas the preliminary report dealt mainly with the *Diatraea* situation in the Colonies where we wish to control it, or with comparable statistics in large foreign sugar-producing countries, like Cuba, the present contribution is concerned mainly with the incidence of *Diatraea* in regions where it is not a pest and where efficient parasites are often present in large numbers. From the nature of the case, the infestation is usually very much less, and the difficulty of obtaining statistical evidence correspondingly greater. The supplementary data on the *Diatraea* situation in the Antilles (recorded in Myers, 1932 b) are not repeated here, but it may be mentioned that *Diatraea saccharalis*, together with its two main parasites, *Microdus stigmaterus* and *Lixophaga diatraeae*, was discovered at last in a primitive association of aquatic grasses in Haiti, indicating that all are probably indigenous. Similarly, in Trinidad, *D. canella* has been taken in a virgin environment, while the evidence for *D. impersonatella* under similar circumstances is doubtful and that for *D. saccharalis* entirely lacking.

Our knowledge of the distribution of the injurious species of *Diatraea* has been extended by Mr. Box and myself, and we now find that *D. canella*, supposedly ranging no further north than Grenada, occurs commonly also in St. Vincent and in St. Lucia. Mr. Box has made valuable surveys in Antigua, St. Kitts and St. Lucia and has added greatly to the list of wild host-plants.

Before we proceed to the regional survey of *Diatraea* and its parasites, a few general questions are discussed, and two parasite introductions are described.

In the preliminary report (p. 85) it was stated that "in no single case has *Diatraea* been found in a virgin plant association," nor was any species of *Diatraea* discovered in savannah grasses. We now know the original host-plants and provenience of *Diatraea saccharalis* in the islands* and on the mainland, and in Trinidad and South America have similarly tracked the three remaining important sugar-cane forms to their original habitats, which include both savannah and forest associations in the case of all of them.

(i) *The influence of rainfall.*—I have stated elsewhere that *Diatraea* infestation tends, other things being equal, to vary directly with moisture (*i.e.*, chiefly rainfall), as first pointed out by Salt in Cuba. This proved to be directly opposed to the results of a very experienced investigator, Dr. Geo. Wolcott. I believe that the discrepancy disappears if the variational tendency be expressed as above, correlated with "moisture," from whatever source, instead of directly with rainfall, for it appears that Dr. Wolcott's heaviest infestations were observed in regions where, although the rainfall was low, the canes were well irrigated.

(ii) *The question of burning trash.*—I am still far from being convinced that burning of trash, either before or after cutting, whatever be the economic *pros*, or the agronomic *cons*, has any significant effect on the *Diatraea* infestation or the balance, if such exists, between it and its parasites. Thompson's proof that an agricultural process which destroys equal proportions of host and parasite populations, fails to affect the progress of control, applies here in the absence of any evidence that the parasites in whatever stage, are more adversely affected than the hosts. In the preliminary report (p. 89) I described a beautiful experiment which chance had arranged, enabling the effect of burning one particular field of Uba cane to be studied over a period of some 4½ years. This field had been burned with unusual severity twice during that period, and the infestation had dropped from an abnormally high figure at the beginning of the period to one so low that it was extremely difficult to find a borer at all. Here, obviously, any effect the burning had had was adverse to the infestation.

An even better case was observed at Central Jaronú, Cuba, in March 1932. For 3½ days, six of us were working on a block of six fields, collecting *Lixophaga* material. These fields were of similar size and surface and soil, all in standover Cristalina cane, all irrigated, and as strictly comparable as already established fields could be. Three fields had been deliberately burned before cutting as a fire-guard or trocha, for the rest of the Colony. These were cut about a week before the other three, so that the *Diatraea* infestation in them had a slight start and should have been more marked. In them, however, we could find no dead hearts, *i.e.*, no *Diatraea* infestation, though I searched for half an hour and the men much longer. In the three unburned fields, on the other hand, there was a considerable infestation—enough dead hearts to keep us all busy for 3½ days of hard cutting. One would almost be justified in assuming that the burning, so far from having favoured the borers at the expense of their parasites, had made a clean sweep of the infestation.

(iii) *The introduction of Lixophaga into the Lesser Antilles.*—In the preliminary report (p. 101) I described an attempt to introduce *Lixophaga diatraeae* from Cuba into Antigua and Barbados. No recoveries were made, and I am satisfied that this attempt was a failure owing to its being largely a single-handed effort, though I had generous help in Cuba, and in Barbados Mr. Tucker spared no pains or skill to establish the parasite. Later experience has shown that speedy establishment of a parasite under West Indian conditions can be secured only by the full-time co-operation

* In Haiti, *Diatraea saccharalis* was found infesting water-grasses (especially *Luziola spruceana*) in primitive plant-associations at Étang Miragoâne. Here it was parasitised to the extent of 50 per cent., half by *Microdus stigmaterus* and half by *Lixophaga diatraeae*.

of an experienced worker on the spot, with the specialist who is making the shipments. Until such co-operation can be organised and maintained in all the main Colonies of the region, biological control will be necessarily hit-or-miss, both in technique and results. With the financial aid of the planting and factory interests in Antigua and St. Kitts, and the enthusiastic co-operation of Mr. H. E. Box in receiving, rearing and liberating the parasites, a second attempt was made in March to May 1932. With the aid of Mr. L. C. Scaramuzza and a skilful labour gang,* the material, to the extent of 6,895 puparia, was collected at Central Jaronú, Cuba, through the great courtesy of Señor Don Antonio Mendoza and Señor Grau, general manager and manager respectively. The fresher puparia were shipped to Antigua by Pan American Airways, while the live borers were kept, as largely as possible, in separate ointment tins, and fed on maize, till they either pupated or produced a parasite. This bred material was, of course, the best, being freshest and less likely to be attacked by hyperparasites. The last shipment, collected and sent off by Mr. Scaramuzza alone, consisted of 1,696 puparia and 56 parasitised larvae, the former including no fewer than 568 reared puparia. In all, seven shipments were made at weekly intervals, the accumulated puparia being kept in an ordinary domestic refrigerator until mail-day. As before, boiled, sifted bagasse, well moistened, was found, in accordance with Dr. Loftin's original suggestion, to be an ideal medium, both for storage and packing, much better and more convenient than Sphagnum.

Arrived in Antigua, a proportion of the emerging flies was mated and liberated in suitable fields, while a certain percentage of gravid females was kept back for dissection, the embryos being distributed among healthy borers and a flourishing laboratory stock thus established and maintained. By means of this technique, originally elaborated by Mr. Scaramuzza, Mr. Box, and in St. Kitts, Mr. Mestier, reared and liberated many thousand more flies from the original material. Recovery in the field was exceptionally rapid in both Antigua and St. Kitts—both within a few months (Antigua, 5 weeks, St. Kitts, about 4 months) of the first liberations. The spread of the fly and the progress of the resulting parasitism was equally speedy.

In 1933 Mr. Box, with financial aid from the industry, introduced *Lixophaga* from Antigua into St. Lucia, and again recovery was rapid, both in the wet lands of the leeward coast and the dry areas of the south-east. At the present time it can be safely asserted that *Lixophaga* is already well-established and distributed in the three islands. A careful mill-survey of borer infestation was instituted very early by Mr. Box, and this, carried out adequately every year, will enable the effect of the introduction to be accurately estimated. The informative reports of Mr. Box (1933) should be consulted for full details of these various introductions (cf. also Moody Stuart, 1933). Mr. Tucker is now introducing *Lixophaga* into Barbados.

The writer was of the opinion that the wetter cane-lands of St. Lucia would prove too moist for *Lixophaga*, and he therefore recommended the introduction of one of the southern Tachinids, for instance, the Amazon fly, for introduction into these districts. It appears, however, that *Lixophaga* is already thriving there. In these circumstances, and since *Lixophaga* does not attack *Diatraea canella*, the second cane-borer in St. Lucia, it might be advisable to import *Paratheresia claripalpis* from Trinidad. The Amazon fly (*Metagonistylum*), is, like *Lixophaga*, largely restricted to *Diatraea saccharalis*.

(iv). *The introduction of the Amazon fly into British Guiana.*—The discovery and status of this promising parasite (*Metagonistylum minense*) are described on p. 227 below, and further details are given in another publication (Myers, 1934). The cost of the introduction into British Guiana was borne by the Sugar Producers' Association, the fund being administered by the Director of Agriculture, thus securing the essential

* As finally selected after considerable trial, this consisted of a Spaniard, a Cuban negro, a white Cuban, a Portuguese and a Haitian.

close co-operation with the local agricultural authorities and the special *Diatraea* entomologist, Mr. L. D. Cleare.

Means of transport on the Amazon near Santarem, where all the material was collected, are confined almost entirely to water. Practically all the puparia shipped, or from which further supplies were reared in the laboratory, were collected by means of boats or canoes. It was necessary at the height of the campaign, to employ a small fleet consisting of a motor-launch (in addition to that carrying the shipments to Pará), a small sailing boat and eleven dugout canoes or montarias. Some of the richest collecting grounds lay ten miles and more from the laboratory, and the frequent rough water at that season, in stretches of open water three or four miles across, made travelling uncomfortable and at times dangerous. The collecting personnel, save for three Arawak and coloured men from British Guiana, who acted as foremen, was entirely recruited locally, and reached a total at times of forty people. The puparia were handled in the same manner as *Lixophaga*, and Mr. L. C. Scaramuzza ascertained that the same rearing technique could be applied.

Transport was the most difficult and expensive part of the campaign. The regular airways supplied a weekly service from Pará to Georgetown, making the journey in one day. The problem lay in covering regularly, and as frequently as possible, the stretch of some 470 miles of river between the collecting base at Santarem and the air-port at Pará. The river steamers, of which there are many, are too irregular or infrequent, and the time at our disposal was insufficient for unexpected delays. The parasites were sent as puparia, the normal period of pupation being about 9 days, which could be extended to a maximum of 13 days by a judicious use of ice. Thus with freshly-reared puparia we had available a maximum of 13 days, and with collected puparia of unknown age, a correspondingly shorter period.

Preliminary enquiries having shown that the cost of a chartered aeroplane was prohibitive, a 26-ft. launch was bought in Glasgow, of a type likely to withstand the heavy seas of the lower Amazon, with a stretch of over 50 miles of open water approaching Pará. This launch proved eminently suitable for the work, and made, without mishap and with clockwork regularity, the journey to Pará and back every fortnight. This, however, was rendered possible only by the courage and devotion of my engineer-captain, Senhor José Paes, to whom a large part of the success of the campaign is therefore due. Towards the end of the very first voyage the pilot declared that to go on through the rough water was suicide. Only the firm determination of Paes forced him on, and thereafter it became a matter of pride on the part of both men to maintain a regular service, to the astonishment of the whole population of the Lower Amazon. By this means the puparia reached Georgetown in five days.

When the work was drawing to a close an aeroplane service was inaugurated between Pará and Manaus, stopping at Santarem. The last shipment was sent by this means; but it was less satisfactory, as the package lay in the post-office in Pará without ice for three days, waiting for the northbound aeroplane.

Altogether six shipments were sent (during August–October), totalling 3,006 puparia. They were received in Georgetown by Mr. Cleare, who reared large numbers of the flies by an elaboration of the Scaramuzza technique, and many liberations were made on selected estates. By the middle of March 1934, only 6½ months after the first trial shipment was despatched from the Amazon, the Tachinid had been recovered in some numbers on six different estates in Demerara and Berbice. It was recommended that rearing and liberation be kept up for another year, and several of the estates took up this work enthusiastically, with the help of East Indian youths trained and supervised by Mr. Cleare.

(v). *Diatraea and its parasites in northern Venezuela*.—Three previous investigators, Messrs. Box, Osborn and Catoni, had visited northern Venezuela to search for parasites of *Diatraea* and of other cane-pests, all on behalf of estate interests in Puerto Rico.

The chief cane-borers in the Caracas Valley and at Maracay are *Diatraea busckella* and *D. canella*. In the former district the following counts of mature stalk-infestation* were made on different estates:—23 per cent. (Salangor), 46 per cent. (BH 10 12), 88 per cent. (Salangor), 44 per cent. (Santo Domingo). The number of counts is, of course, too low to yield any information on varietal susceptibility.

On the Caribbean littoral, I found at La Guaira an infestation of *D. busckella* alone, while at Mamo, just west of this, H. T. Osborn (oral communication) found *D. saccharalis* common. Much further east, at Carúpano, the predominant borer in young canes was *D. canella*, with an occasional *D. saccharalis*.

We found a striking absence of wild grass-hosts of *Diatraea* in northern Venezuela. The only infestation outside cane was in the tall, stout grass, *Panicum grande*, six to eight feet high, at Ocumare de la Costa, and here the only species was *D. saccharalis*.

In the cane-lands it was very difficult to obtain sufficient material for parasite studies. This was especially the case in the Valley of Caracas, where young shoots (the most convenient collecting-ground) were scarcely infested at the time of our visit. Four cases were found (on *D. canella* where recognisable) of attack by a Muscoid larva, possibly the same as the *Sarcophaga* sp. reared by Box in 1926, but how far this is a scavenger and not a regular parasite is uncertain.

In the valley of Valencia inadequate material of *Diatraea canella* from cane showed a parasitism of about 13 per cent. by *Microdus*, and about 7 per cent. by *Paratheresia claripalpis*, but the figures are hardly significant.

At Carúpano about 8 per cent. of the *Diatraea* in cane were parasitised by *Paratheresia claripalpis*, but again the figures are not significant.

Actually considerably more material was obtained from the wild *Panicum grande* at Ocumare de la Costa. In this host *D. saccharalis* was attacked to the extent of 3.5 per cent. by *Ipobracon* sp. (not reared) and at a similar rate by a predacious beetle larva. Considering the low rate of parasitism, the abundance on the grasses of adult *Ipobracon puberuloides*, a well-known parasite of *D. saccharalis*, was surprising.

(vi). *Diatraea in the Venezuelan llanos*.—No infestation was found in cane or maize in the small patches of these plants near ranch-houses on the llanos. On the Guárico river, wild rice, *Oryza latifolia*, was bored by a *Diatraea* and parasitised by a *Microdus*.

A general infestation by three economic species, *D. saccharalis*, *D. impersonatella* and *D. busckella*, occurred in the high grass savannah bordering the Rivers Apure and Portuguesa, the host being *Paspalum fasciculatum*. *D. saccharalis* was much the most abundant, accounting for about 96 per cent. of the infestation, and occurred in the less common grasses, *Paspalum repens* and *Echinochloa polystachya*.

Larvae from *Paspalum fasciculatum* were attacked by natural enemies to the extent of 16 per cent., a *Microdus* (not reared) being responsible for 2.4 per cent., *Ipobracon* (*I. puberuloides* where reared) for 3.9 per cent., *Paratheresia claripalpis* (a small pale form) for 6.8 per cent. and a predacious beetle larva for 2.9 per cent.

(vii). *Diatraea in the Delta of the Orinoco*.—As already mentioned, the sugar-cane of the small Indian and Venezuelan patches was apparently free from infestation by *Diatraea*. *D. saccharalis* occurred in beds of the floating *Paspalum repens* where these lay in forest creeks, but not where the same creeks flowed through open savannah. The only parasite found was *Microdus sacchari*, killing about 13 per cent.

(viii). *Diatraea in the interior of British Guiana*.—In addition to records included in sections (vii) and (x), *Diatraea impersonatella* was found boring *Paspalum arundinaceum* (a new host-plant), and *D. saccharalis* boring maize, at the mouth of the

* I have elsewhere pointed out that under travelling conditions it is often impossible to make more than a stalk-infestation count, though this is admittedly less reliable than a joint count, as an indication of the damage caused.

Rupununi river. In *P. virgatum* the stinging ant (*Solenopsis* sp.), which so frequently takes possession of clearings in this region (cf. also Fordlandia, Rio Tapajoz), was predacious on the larvae. Extremely small infestations of *D. saccharalis* were seen in Indian provision-patches in the Pakaraima and Kanuku Mountains. On Shiriri Mountain, an outlier of the latter, the forest grass, *Setaria vulpiseta*, was heavily attacked by *Diatraea brunnescens* parasitised by *Paratheresia* sp. (apparently not *P. claripalpis*, but the material is inadequate), *Microdus*, *Ipobracon*, *Spilochalcis*, *Cordyceps* and a purple fungus. A very large proportion of the larvae were aestivating in dead dried stalks, and were still in this state when these words were written six months afterwards. In Trinidad a similar species (*D. bellifactella*), here attacking *Setaria* (*Chaetochloa*) *sulcata* in cacao plantations, has been found by Mr. Box to be parasitised by a very interesting gregarious *Ipobracon* with the pupating habit of an *Apanteles*, though its cocoons still retain their straight sides and flat ends, by *Microdus* and by *Spilochalcis*, all of which are still to be described.

On the flood-plains of the Napi, flowing through the heavy rain-forest at the base of the Kanukus, *Diatraea impersonatella* was found, not abundantly, in *Paspalum virgatum*. It was attacked to the extent of 8 per cent. by a *Spilochalcis* (pupal parasite). No other parasites were found.

An opportunity was taken to examine the *Diatraea* situation on some of the wet savannahs which back the sugar estates. For this purpose several days were spent at Lama Stop-off. No host-plants of *Diatraea* were found save a few odd razor-grasses (*Paspalum virgatum*) growing under entirely artificial conditions on a dam. These were lightly infested with *Diatraea canella*. The wet savannahs, therefore, in confirmation of the results already obtained under more primitive conditions in the Orinoco, do not form a reservoir of borer infestation.

The *Sarcophaga* recorded in the preliminary report (p. 93) as attacking *Diatraea* in Berbice has been determined as *Sarcophaga* sp. near *helicis*, Towns.

(ix). *Diatraea in Dutch Guiana*.—The only important cane-attacking species are *D. saccharalis* and *D. canella*. A few counts of stalk infestation in sugar-cane were made in Nickerie, showing no significant difference from the usual British Guiana infestation. The first lot, D625, from old land, cultivated about 40 years and without manure for two years, 4th ratoons, very heavy canes, showed a stalk infestation of 78.1 per cent. D625 from older land still, cultivated at least 100 years, and without manure for the last three, about 8th ratoons, very heavy canes, was 93.3 per cent. bored. D625, plant canes from virgin soil (see p. 207), exceedingly heavy canes, was bored 89.7 per cent. This last lot had a stalk-infestation by *Castnia licoides* of about 2 per cent., and much *Metamasius*, while the other two lots were free from both. A mixed lot of larvae of *D. saccharalis* and *D. canella*, from D625, was parasitised about 6 per cent. by *Ipobracon*, which was not reared.

(x). *Diatraea in the Rio Branco-Rupununi savannahs*.—An astonishing feature of the *Diatraea* investigation, up to the time of the first Brazilian journey in 1932, was the complete failure to find *Diatraea* in any savannah association save the riparian grasses of the lower llanos. On the Rupununi savannahs, in some of the baixas or low areas which turn into swamp in the winter, the grasses *Andropogon bicornis*, *Paspalum millegrana* and *P. densum* are bored by *Diatraea canella* (in the only first grass) and *D. impersonatella* (in all). Most of those in the first grass are *D. canella* with some *D. cayennella*. *Cordyceps* is found sparingly, but no parasites. A new small *Diatraea* (*D. savannarum*) and another determined provisionally as a form of *D. impersonatella* attack *Paspalum plicatulum* in similar situations, the latter being sometimes attacked by *Cordyceps*. On the Lower Takutu a few odd clumps of *Paspalum millegrana* were lightly infested by another *Diatraea*, not yet determined.

A very heavy infestation by *Diatraea saccharalis* occurred in maize grown in an old corral in the Rupununi savannahs. There was very slight parasitism by an *Ipobracon* (only an empty cocoon found). Broom-corn growing among this maize,

and keeping green for some time after the latter had dried, was very lightly infested by the same *Diatraea*. Larvae from maize showed a parasitism of 1·8 per cent. by an *Ipobracon* which was not reared.

The occasional small beds of *Panicum elephantipes* on the Upper Rio Branco and the lower Uraricuera were apparently not attacked. Borings were found in the wide beds of *Paspalum anceps* bordering the fringe-forest and some of the bush-islands, and *Ipobracon* was unusually plentiful (an undescribed species, and a few *I. dolens*), but no *Diatraea* was found.

On the higher savannahs near Roraima *Diatraea* was scarce. *D. impersonatella* was boring in *Avonopus scoparius* at an open stream margin about 4,500 feet up the slopes of Roraima itself.

(xi). *Diatraea on the Lower Amazon and Lower Rio Branco*.—On the rivers in the vicinity of Pará and Igarajé-mirim, *Diatraea* attacks cane rarely. It is, in fact, a pest of no importance not only here, but throughout the Lower Amazon. A count made in *cana branca* near Igarajé-mirim showed a stalk-infestation of 17 per cent., but in other cases it was much harder to find, even in mature canes, and almost impossible in shoots. Wild rice, *Oryza latifolia*, growing among canes was slightly infested by *D. saccharalis*. In the mature canes most of the bores were abandoned, and it was not possible to ascertain the main species concerned, but it was almost certainly *D. saccharalis*. *Paspalum virgatum* growing by roadsides and about house-clearings was bored by *D. impersonatella*. Further up the Amazon, at Jararacá, these borers were parasitised at the rate of about 28 per cent. by *Paratheresia clari-palpis*.

Near Almeirim the first floating grass-beds of *Paspalum repens* appear, with *D. saccharalis* parasitised by *Microdus stigmaterus*. The beds reach their maximum development about Santarém, where all the collections of the Amazon fly (*Metagonistylum minense*) were made. Infestation of *Paspalum repens* is often very high; in fact, in restricted areas and at certain stages of growth of the beds, the surface of the latter was brown with dead hearts caused by this borer, no other *Diatraea* species being found in this grass. The chief parasites are *Metagonistylum minense* (up to 40 per cent.), *Microdus stigmaterus* (up to 27·4 per cent.), *Stomatodexia diadema* (up to 16·5 per cent.). The *Ipobracon* were not distinguished in the larval stages, but of the two species present, *I. dolens* was reared more often, *I. puberuloides* being much rarer. I have not, as in the preliminary report, given the mean parasitism of all material collected from the one host-plant, since the rate varied so tremendously and not always predictably from place to place, any one of the above parasites being frequently entirely absent. These beds of *Paspalum repens* were our chief collecting grounds, and as the needs of the collecting-campaign were paramount, we naturally tended to concentrate more and more on localities where the Amazon fly was more abundant. It is more than probable, therefore, that the maximum rate of parasitism by *Microdus* and by *Stomatodexia* might, in other spots, have reached as high a figure. In other words the maximum figure for *Metagonistylum* is probably a true one, while that of the other parasites errs on the low side. The greatest single factor definitely correlated with variation in the abundance of *Metagonistylum* was the relative number present of the other fly-parasite, *Stomatodexia diadema*. Whether the influence of the latter is a matter of direct competition, or, on the other hand, could be explained by ecological factors in one place favouring *Metagonistylum* and in another *Stomatodexia*, we could not ascertain. In only one case were larvae of the two parasites encountered in one host. This was in an association where the rate of parasitism by *Stomatodexia* was 16·5 per cent., that by *Microdus* 12 per cent., and that by *Metagonistylum* only 0·5 per cent. The Amazon fly larva was dead, while the other was alive and healthy; both were about half-grown and of similar size. *Stomatodexia* often infest very young *Diatraea* larvae when they first leave the grass-blades and burrow into the shoot; *Metagonistylum*, on the other hand, was never

found in larvae so young. Whichever way the influence works, it may be taken as a happy augury for the success of the Amazon fly in British Guiana that *Stomatodexia* is there very local and rare. A few typical examples may be given of the proportions of the two flies in different populations of the host at Santarem.

Population	E	<i>Metagonistylum</i>	39	<i>Stomatodexia</i>	3
"	F	"	18	"	1
"	G	"	1	"	17
"	H	"	4	"	17
"	M	"	30	"	0

It is a curious fact that in the intensive investigations carried out in 1929 (Preliminary Report) on *Diatraea* parasites in British Guiana, *Stomatodexia* was never found in wild grass-hosts.

Two other factors influence the status of the Amazon fly in the Santarem district. One is the rare presence of hyperparasites, three species of which (2 ENCYRTIDAE and 1 Pteromalid) are in the hands of the Imperial Institute of Entomology for determination. Some idea of their infrequency may be derived from the fact that during the collection and rearing of some 3,000 puparia of *Metagonistylum*, only six cases of hyperparasitism were encountered. This does not, however, present a true picture, since practically all the hyperparasites occurred in residual host populations, at the end of infestations in drying and dying grass-beds. Very few hyperparasites were found in the younger infestation-stages which gave us the bulk of our material. One of the hyperparasites, a small, black, beetle-like Encyrtid, attacks *Stomatodexia* too, and may therefore occur also in British Guiana, associated with that host.

The other factor possibly influencing to some extent the status of *Metagonistylum* is the competition between it and two other main parasites of *Diatraea* on the Amazon. The first is the fly, *Paratheresia claripalpis*, also present as a rare insect in some Demerara cane-fields. With this there is no competition in *Paspalum repens*, for *Paratheresia* was found there only once (by Mr. Scaramuzza); but it occurs more abundantly in *Paspalum fasciculatum* and (elsewhere) in sugar-cane, both of which are frequented by *Metagonistylum* also.

The other common parasite of *Diatraea* on the Lower Amazon (second in fact only to *Metagonistylum*, and probably more widespread) is the Braconid, *Microdus stigmaterus*. Here there was no sign of the close relation existing between the number of *Metagonistylum* and that of *Stomatodexia*. There was, however, considerable evidence that *Microdus* and *Metagonistylum* prefer the same habitat; and there was a slight indication of actual competition between them. In two cases a host larva contained an example of each parasite, and in both cases the *Microdus* died when nearly full-fed, while the Amazon fly successfully pupated. There seemed to have been no shortage of food. Such advantage as there is would appear, therefore, to lie on the side of the Tachinid. *Microdus stigmaterus* is present abundantly in British Guiana, and in fact up to Cuba, on *Diatraea* in grasses, but as a check on borers in cane it is usually practically negligible.

It is curious that all the *Microdus* reared from *Diatraea* on the Amazon, or flying among infested grasses, were *Microdus stigmaterus*. The other two species attacking *Diatraea*, namely *M. sacchari* and *M. parvifasciatus*, seem so far to be confined to British Guiana and Trinidad.

There are three very surprising gaps in the ranks of the parasites attacking *Diatraea* in *Paspalum repens* near Santarem. One is *Ipobracon grenadensis*, one of the commonest parasites of *Diatraea* spp. in Guiana, Trinidad and Grenada—a large showy species very hard to overlook. The second is *Spilochalcis* (*Heptasmicra*) *dux*, a common pupal parasite (especially in grass-hosts) in British Guiana and Trinidad. In all the material handled at Santarem, and in 127 pupae specially dissected for the purpose, no trace of this parasite was found. Its absence is the more remarkable

from the fact that it was numerous about 150 miles further up the Amazon on the same host in the grass, *Echinochloa polystachya*. The third lack is that of any species of *Cordyceps*, no sign of which was found in any host-plant on the whole Lower Amazon. The fungus parasites of *Diatraea* are frequently surprisingly abundant in a dry climate, e.g., that of Antigua (where, however, the relative humidity is unexpectedly high).

Canarana (*Echinochloa polystachya*), the second largest component of the floating grass-beds, occurs usually landward of the *Paspalum repens* when the two are together, and can survive a certain amount of drying on the bank itself, but it then, as I have explained elsewhere, becomes largely unattractive to *Diatraea*. The common borer, and in fact the only one found by us, was *D. saccharalis*, attacked by *Metagonistylum*, *Stomatodexia*, *Microdus stigmaterus*, *Ipobracon dolens* and *Spilochalcis dux* (not at Santarem).

Between Santarem and Manáos, a wide zone of the stout grass, mory (*Paspalum fasciculatum*) is a constant feature of the riparian vegetation, behind the canarana. It is attacked, sometimes heavily, by several species of *Diatraea*, including *D. amazonica*, *D. myersi* and *D. saccharalis*, the commoner parasites being *Microdus stigmaterus*, *Metagonistylum* and *Spilochalcis dux*. *Diatraea saccharalis* occurred in a new host, *Leptochloa panicoides*. *D. albierinella* was found with *D. saccharalis* in sugar-cane, where they were parasitised by *Metagonistylum*, *Spilochalcis dux* and *Prophanurus* sp. (egg parasite), at Paraná da Eva.

Infestations of *D. saccharalis* were found likewise in a large *Hymenachne* (not in flower) and in *Echinochloa crus-garonis*, a new primitive host-plant, in which the attack was heavy.

While the expedition was held up in Manáos awaiting a permit to proceed under the new law, Mr. Scaramuzza was dispatched to the sugar-growing district of Janaúacá, up the mouth of the River Solimões. He found there a *Diatraea*, provisionally determined as *D. canella*, boring in cane. There was a lake with huge beds of floating grasses, apparently chiefly *Paspalum repens*, infested with *D. saccharalis*, very heavily parasitised by *Stomatodexia diadema* and less so by *Microdus stigmaterus*, *Ipobracon dolens* and *I. puberuloides*. The apparent absence of the Amazon fly is noteworthy.

Short observations were made on two other rivers. At Fordlandia, 111 miles up the Tapajoz, the fairly extensive floating and riparian grass-beds (*Paspalum repens*, a stouter undetermined species, and *Oryza latifolia*) are much less luxuriant than those of the yellow water rivers. *Paspalum repens* was lightly infested with *Diatraea saccharalis* (a typical form) and the new grass (unfortunately not in flower) by a form of the same species. The only parasite found, in striking contrast to Amazon conditions, were *Ipobracon dolens* and a *Microdus*, both on the second infestation. The *Ipobracon* was attacking the borers at the rate of 13 per cent., exclusive of a surprisingly large proportion of larvae paralysed but not parasitised, probably by this species. *Microdus* was attacking only about 4 per cent.

At the mouth of the Rio Branco, in a house-clearing, while both *Paspalum virgatum* and *P. fasciculatum* were abundant and there was a considerable patch of sugar-cane, borers were very rare, and the search was a painful process on account of the fire-ants, *Solenopsis saevissima*, which were in complete possession of the grass patches. *D. saccharalis* was present in the *P. fasciculatum*, attacked by an *Ipobracon* (not reared). An undetermined *Diatraea* pupa was found both in the cane and in the *P. virgatum*, the latter producing a *D. saccharalis*.

(xii). *Diatraea* in the Santa Marta district of Colombia.—The chief borer, on inferior cane under irrigation, is apparently *D. busckella*. This is the typical form as determined by Mr. Box, the common Venezuelan variety with pinkish flush in both adult and larva being *D. busckella* var. *rosa*, Heinr. In the field examined in April,

about 50 per cent. of the unjointed to 3-jointed shoots were killed by this borer—the highest infestation of shoots among tall canes that I have seen. The borings were great tunnels extending up the stalk, like exaggerated *D. canella* damage, or even like the work of *Castaia licoides*. No parasites were found, but two predators, a small ant and a *Geophilus* were encountered.

(xiii). *Diatraea* in the Colón district of Panama.—*Diatraea* seems very rare in cane. In canes exposed for sale (and thus probably to some extent selected) about 2 per cent. of the joints were bored. At Gatun *Paspalum virgatum*, in remarkably thick roadside clumps, showed a very low infestation by *Diatraea busckella*, parasitised by *Paratheresia claripalpis*.

(xiv). *List of Diatraea parasites in the regions visited*.—The *Diatraea* parasites and predators in the regions visited may be listed for purposes of reference, as follows, in approximate order of importance:—

Northern Venezuela.—*Paratheresia claripalpis*, *Microdus* sp., *Ipobracon* sp., predacious beetle larva.

Venezuelan llanos.—*Paratheresia claripalpis*, *Ipobracon* sp. (chiefly *puberuloides*), *Microda* sp., predacious beetle larva.

The Orinoco Delta.—*Microdus sacchari*.

The forest interior of British Guiana.—*Paratheresia* sp., *Spilochalcis* sp., *Microdus* sp., *Ipobracon* sp., *Cordyceps*, *Solenopsis* sp. (predator), a purple fungus.

Dutch Guiana.—*Ipobracon* sp.

Rio-Branco-Rupununi savannahs.—*Cordyceps*, *Ipobracon*.

The Lower Amazon.—*Metagonistylum minense*, *Microdus stigmaterus*, *Stomatodexia diadema*, *Paratheresia claripalpis*, *Ipobracon dolens*, *I. puberuloides*, *Spilochalcis dux*, *Prophanurus* sp.

Santa Marta, Colombia.—Small ant, *Geophilus* (both predators).

Colón, Panama.—*Paratheresia claripalpis*.

Several of these lists must obviously be very incomplete.

(xv). *Summary on Diatraea and recommendations*.—The only outstanding and economically important new *Diatraea* parasite discovered in the areas visited is the Amazon fly (*Metagonistylum minense*), now, with Mr. Cleare's co-operation, established in British Guiana.

The greatest present need in the *Diatraea* problem is a specific parasite for *D. canella*, the second most destructive borer in Guiana and through the islands to and including St. Lucia (but not Barbados). Mr. Box has shown definitely that *Lixophaga* will not attack it, and Mr. Cleare has had similar results with the Amazon fly. Experiments are now being carried out in Trinidad by Mr. Pickles and myself to see whether *Paratheresia* will prefer *D. canella* to the other species. *D. saccharalis* is primitively attached to much more hygrophilous (even aquatic) plant associations than *D. canella*, or in fact than any other *Diatraea*. It has managed in the course of centuries to adapt itself to cane growing under much drier conditions, but most of its parasites have not been able to follow it. To this, *Lixophaga* is a notable exception, and its avoidance of *D. canella* must be due to intrinsic influences and to the fact that it has only been brought into contact with *D. canella* by man, their ranges not overlapping.

Paratheresia is a very adaptable species occurring over a wide range of conditions from Argentina at least to Panama. It attacks a considerable number of hosts, including a cane-boring weevil, *Acrotomopus atropunctellus*, Boh., in northern Argentina. Its preferred plant-associations are generally those in which *D. canella* and *D. impersonatella* are plentiful, but not *D. saccharalis*. Its position in British Guiana is very curious. In Berbice it does not occur, while in Demerara it is found, and then very rarely, only on two estates in the immediate vicinity of Georgetown.

It seems to me either that conditions in the British Guiana coastlands are too wet for it, or that it has only been recently introduced (either accidentally or, like witchbroom on cacao, naturally). Against the first hypothesis is the occurrence of large areas of heavily infested razor-grasses (*Paspalum virgatum* and *P. millegrana*) offering apparently ideal ecological conditions. In favour of the second hypothesis is the great abundance of *Paratheresia* in localities so near as Trinidad and Venezuela, separated by barriers of sea or forest, which the fly may have taken centuries to cross, the razor-grass plus sugar-cane associations of the Guiana coast-lands being of comparatively recent artificial origin and forming a new ecological island. Undoubtedly the primitive conditions of the coast-lands (wet savannahs alternating with swamp-forest) would have been entirely unsuitable for *Paratheresia*. It may be worth while to attempt the extended colonisation of this fly on estates in Demerara and Berbice. It does not, however, seem likely from the preliminary work of Mr. Pickles in Trinidad that *Paratheresia* will prove a promising parasite for *D. canella*, since in the same host-plant it definitely prefers *D. impersonatella* and *D. saccharalis*.

Diatraea saccharalis in British Guiana and the northern islands may be left to the parasitism of the Amazon fly and of *Livophaga*, but an annual survey of the infestation must be maintained, and *Livophaga* should be introduced also into Nevis, where a new cane industry is beginning.*

In future explorations an assiduous search should be made for a specific parasite of *D. canella*. In British Guiana, where it is commonly known as the "yellow head," it is second in abundance only to *D. saccharalis* (the "black head"), which it sometimes exceeds in numbers in young shoots, while *D. saccharalis* predominates in jointed canes and is responsible for the greater part of the mill loss.

There remains the question of *D. impersonatella* in Trinidad, where it is by far the most injurious species, forming perhaps 90 per cent. of the small borers attacking cane in the Naparimas. This problem is receiving fresh study from Mr. Pickles and the writer, while Mr. Cleare is making experiments in Georgetown to determine whether the Amazon fly will attack *D. impersonatella*.

(b) *Large Moth-borer* (*Castnia licoides*).

(i). *Status and host-plants in the regions visited*.—There is considerable evidence that *Castnia* is increasing as a cane-pest in British Guiana (especially East Bank, Demerara) and in Trinidad (Naparimas and Central Plain). This evidence consists partly in the experience of the agriculturists themselves and partly in my impressions from visiting the same estates at intervals during the last six years. In the intervals between severe froghopper outbreaks, *Castnia* is undoubtedly the most serious pest of sugar-cane in Trinidad. In the lee of the Northern Range I have seen cane-carts of peasant cultivators showing a stalk-infestation of at least 90 per cent. Detailed distribution and infestation surveys, on the lines of those carried out by Mr. Urich many years ago (but unfortunately never published) and of those made on *Diatraea* by Mr. Box and Mr. Cleare, are badly needed.

The chief alternate host of *Castnia licoides* in Trinidad is the Musaceous *Heliconia Bihai*, but it is by no means abundant in this host, even in the rain-forests of the Northern Range, where it occurs up to an elevation of some 2,000 feet. It occurs in *Paspalum virgatum* in the cane-lands and also in rain-forest clearings in the Southern Range. Adults have been seen resting on *Heliconia humilis*, which is probably another host; but I have searched in vain in the smaller savannah plant, *Heliconia psittacorum*, which Moore reports as occasionally attacked in the British Guiana cane-lands.

In Northern Venezuela *Castnia licoides* is rare. I have seen specimens of the adult caught there, and found one small larva, apparently of this species, in sugar-cane.

* This has since been done by Mr. Box.

In British Guiana, Mr. Cleare has lately reared *Castnia licoides* from rootstocks of ginger in the N.W. District, while Mr. Moore records it in razor grass and *Heliconia psittacorum* on the coastlands. Mr. J. D. Gillespie sent us a larva, apparently this species, from a Bromeliad in the N.W. District. *Heliconia Bihai*, locally known as wild plantain (in Trinidad "balisier"), was first found as a host-plant in the same district by my wife in 1930. Later observations on its incidence there have been published elsewhere (Myers, 1932 *b*, pp. 268-270). It is much more abundant in scattered clumps of *Heliconia* growing in tall, more or less virgin forest, than in solid "reefs" of the host-plant in more recent clearings. In the former sites, the infestation by stools may be as high as 30 per cent. The young larva begins boring high up the stalk, probably where the egg is laid; it works upward for a time and then descends, all large larvae being found at or below ground-level in the much more solid substance of the rootstock, rendering collecting a hard task, with a mattock essential. In plantain, on the other hand, presumably in correlation with the greater thickness of the pseudostem, full-fed larva may be found 6 feet up, and in cane at a height of several feet, though there again, they prefer the stool. In all hosts they tend to leave the stool and ascend the stem some distance, even 5 or 6 feet, to pupate.

In nearly every provision-patch of Indians or white settlers in the Delta of the Orinoco it was boring cane abundantly, and bananas and plantains almost wherever present. An adult was caught at Santa Elena de Uairae, on the Venezuelan border near Roraima, but local sugar-cane seemed free from borings; *Heliconia Bihai* was plentiful. The larvae were present but scarce in Indians' sugar-cane in the rain-forest at the foot of the Kanuku Mountains; they are more abundant in feral bananas in the same forest. In Dutch Guiana (Nickerie) the attack on cane was slight, none being found in ratoon cane from old fields, and about 2 per cent. stalk-infestation from plant canes in virgin soil. At the mouth of the Rio Branco, *Paspalum virgatum* in house-clearings was lightly infested and the same host was attacked on the roadside between Pará and the coast, and in rain-forest clearings at Fordlandia, Rio Tapajoz, but always sparingly. A slight infestation occurred in sugar-cane near Igerapé-mirim, in contrast to the heavy attack under very similar conditions in the Orinoco Delta.

(ii). *Present control measures.*—In the preliminary report I wrote (p. 102) that "*Castnia* has now been almost entirely controlled in British Guiana by flooding . . . which is rendered easy by the superfluity of water and the ubiquity of canals." The position has changed considerably since then, and in spite of the facilities for flooding, *Castnia* is now regarded as a very serious pest on many estates. Next to the small borers (*Diatraea* spp.) it probably causes more damage than any of the other regular cane-pests, the destruction by cane-lice (aphis) and by hardbacks being sporadic, as to both time and place. There are several factors contributing to the changed status of *Castnia*. In the first place, there are wide areas, notably on the west coast back-lands, where the soil is so pegassy that sustained flooding is impossible—the water runs through it. In addition, the regular flooding for fallowing purposes, though it kills any *Castnia* which may have remained in the field, has naturally no prophylactic effect, and re-infestation may and usually does begin as soon as the new plants are old enough. The *ad hoc* 72-hour flooding for *Castnia*, though theoretically a perfect control, is too expensive to be employed save against heavy infestations. I say "theoretically perfect" advisedly, because there are several practical difficulties in its operation. Some managers complain that 72-hours' flooding adversely affects the canes. Controlled experiments do not confirm this, but in actual practice injury may occur to already weakened canes, and there is the further complication that 72 hours' submergence of the general field surface almost necessarily involves longer and more deleterious submersion at drain corners and low-lying spots. Again, fields with poor drainage are apt to remain water-logged for an injurious period after the 72 hours.

Where, for any of the above reasons, flooding is not practised, or where, as in Trinidad, it is generally impossible, the *Castnia* infestation is still often attacked by borer gangs, youths or women, who are paid so much for a larva or adult moth, according to the abundance of the pest, the price being adjusted to give the average members of the gang a living wage. In British Guiana, for instance, on one estate in March, the price was one cent (a halfpenny) for 3 larvae. In Trinidad, in April, it was one cent for 4, with a maximum set at 160 larvae a day.

(iii). *Natural enemies of Castnia*.—The only known insect parasite of *Castnia licoides* is the Tachinid, *Zenillia palpalis*, Aldrich 1932, discovered in the North-West District of British Guiana, on the edge of the Orinoco Delta, in February 1931. This find followed directly on the discovery by my wife of *Castnia* in a primitive host-plant, namely, *Heliconia Bihai*, in the same district. The larvae of this parasite, to the number of 4 to 40 or more attack the *Castnia* larva and emerge when full-fed from the pupa or prepupa after the host-cocoon is completed, in which they pupate.

As in the case of the Amazon fly, the infestation and parasitism of *Castnia*, even in the one wild host-plant, under different conditions, varied so greatly that a blanket figure of the rate of parasitism in all the material collected is of little value. It amounted to about 2.3 per cent. by *Zenillia* and about 0.8 per cent. by a species of *Cordyceps* (fungus parasite). In restricted localities, larvae collected from *Heliconia* showed a parasitism up to 8 per cent. The puparia of *Zenillia* were attacked by two species of hyperparasites, a *Trichopria* sp., which parasitised very young puparia, and a tiny, squat black Chalcidoid affecting almost fully-formed pupae in the puparia. Some 25 per cent. of the parasitised hosts were thus hyperparasitised, but the *Zenillia* cocoons in each instance showed only a proportion attacked, the others producing healthy flies. This high incidence of hyperparasitism, combined with other signs, seemed to indicate that in March the infestation cycle was drawing to a close, and that some months earlier would be the best time to collect parasite material for introduction. The greatest need for the next introduction campaign is a simple and efficient method of rearing *Castnia en masse*.

Other natural enemies in the same host-plant in the North-West District included a large predacious Elaterid larva (*Pyrophorus ignitus*, F.) and the Phrynid, *Thelyphonellus amazonicus*, Butler, both rare—the former occurring in the proportion of 3 to 500 *Castnia* larvae, and the latter, of 1 to 500.

An abortive attempt was made to introduce the parasite into Trinidad, but difficulties in the mass-rearing of the host were not overcome. Under the necessity of maintaining and rearing some 500 huge larvae of *Castnia* in separate containers, we ran out of tins in the bush, and had to make shift with tobacco tins and rough cases made by fitting together joints of bamboo. In these circumstances sickly larvae were attacked by Phorids in some numbers, while in the apparently healthy ones the *Zenillia* larvae died wholesale and were found by dissection to be brown and half-developed.*

(c) *Froghoppers (Tomaspis spp.)*.

(i). *Status and host-plants in the regions visited*.—Like *Diatraca*, the froghopper is apparently indigenous in the area where it is a pest, and is represented elsewhere by the same and by numerous other species. The Trinidad form (*Tomaspis saccharina*) is, however, restricted in its range to Trinidad, Grenada and St. Vincent (a doubtful record), even the Tobago species being distinct. Although some of the froghoppers studied elsewhere, e.g., *Tomaspis bodkini*, are extremely nearly allied to *T. saccharina*, the generic term *Tomaspis* is used in this report in its widest sense. One of the most

* These dead larvae when past the first instar were attached to the body wall, and invested in complete sheaths of host tissue, covered with a close net-work of host-tracheae. The snow-white colour of the sheaths was in striking contrast to the brown, more or less decomposed bodies of the parasite larvae. The younger examples of the latter were loose in the body cavity.

pressing needs of the froghopper investigation to-day is a systematic study of this genus and the segregates which have been suggested in it, with special reference to those most closely related to *T. saccharina*. Until this is forthcoming, on the lines of the very valuable revision of *Diatraea* by Box (1931), the comparative ecological studies made outside Trinidad by Mr. Pickles and myself are not immediately utilisable. In the preliminary report the froghopper position was described in the Greater and Lesser Antilles and in British Guiana, with a summary of other infestations from the literature. The following sections cover the new regions visited.

(ii). *Froghoppers in Northern Venezuela*.—A species very close to *Tomaspis saccharina* was found in the Valley of Caracas, after a very long search. It is probable that adults would be more abundant there in the wet season. They were first found in a dry cane-field ditch, full of *Paspalum conjugatum* and *Commelina* sp., the banks clothed with *P. conjugatum* and Guinea-grass, in places passing wholly into the latter. A second infestation was seen on sugar-cane itself in a damp hollow, the adults sitting conspicuous on the leaves, not in the leaf-funnels like the Trinidad species. A froghopper of the genus *Clastoptera*, found only as nymphs, occurred on orange trees, sparingly. At Ocumare de la Costa, besides the *Clastoptera* already mentioned as infesting cacao, no froghoppers were found, though very likely-looking beds of *Paspalum conjugatum* and *Panicum polygonatum* were assiduously searched.

(iii). *Froghoppers in the Orinoco Delta*.—*Tomaspis bodkini*, Williams, occurs commonly on some, but by no means all, of the elevated aboriginal clearings already described, chiefly on the sandy knolls. There, in the space round the Indian huts, are grassy patches containing *Paspalum conjugatum*, *Syntherisma digitata*, *Panicum pilosum* and occasionally a small, fine-leaved *Cyperus*. *P. conjugatum* is dominant and is the preferred host of *Tomaspis bodkini*, which occurred, however, also on the *Syntherisma*. *Tomaspis pubescens* (provisional identification) was usually present in the same company, but nearly exclusively on the *Paspalum* and the small *Cyperus*. No infestations were found on cane.

(iv). *Froghoppers in the British Guiana interior*.—Rain-forest conditions in the North-west District are similar to those of the adjoining Delta, and the above two species occur. It is surprising that long stretches of such favourable grasses as *Panicum pilosum* and *P. stoloniferum* are often not infested. *Tomaspis rubra*, attached especially to second-growth shrubbery, is much more abundant than in the Delta. *T. lineola*, a forest species, probably not attacking grasses, is rather frequent at light, where also *T. rubra* occasionally occurs. Including another, large red forest species, there are five *Tomaspis* spp. in this district. These recur in suitable localities throughout the forested interior as far as Roraima, *T. bodkini* and *T. pubescens* reaching to an altitude of about 2,700 feet. In the heavy rain-forest at the foot of the Kanuku Mountains another species was very abundant on *Hymenachne auriculata* (associated with *T. pubescens*) and on *Tripsacum dactyloides* in an association already described. On the wide blades of the latter, where it was in pure culture, it was producing a browning closely similar to froghopper blight of Trinidad. Another sucking-insect, a white Derbid, also infesting this host, may have been associated in this injury.

In the varied higher forests of the Pakaraimas 3 other species of very large *Tomaspis* (sens. lat.) occurred, making a total of 8 forest forms in British Guiana. There are in addition the two savannah forms considered in the next section.

The distribution of the forest forms is very interesting, especially under the varied conditions of the Pakaraima Mountains. *Tomaspis* occurs by far the most frequently in lowland mixed rain-forest. Their predominance in this type of forest is especially marked when we include second-growth bush, which is usually mixed. Fewer individuals occur in montane mixed rain-forest, mora, and asheroa forest, and none were seen in deciduous woods, nor in what I have called coppice-forest (cf. p. 205).

(v). *Froghoppers on the Rupununi-Rio Branco savannahs*.—At least two species of savannah froghoppers occur in British Guiana, of which the more important,

Tomaspis flavilatera, attacking sugar-cane, has not been encountered in the settled areas again. One specimen resembling this was discovered by Mr. Pickles on the Rupununi savannahs while a third, (*T. rhynchosporae*), of which the host-plant is the sedge *Rhynchospora barbata*, is scarce but widespread in the Rupununi, and on upland savannahs near and on Roraima, up to an elevation of about 6,300 feet. This latter species, which is a very small *Tomaspis*, was abundant at the latter elevation, and also in a restricted area at about 4,000 feet, where a small stream led a band of swamp across the drier *Trachypogon-Byrsonima* savannah. Between the swampy zone and the latter was a zone marked by abundance of a tall wiry *Andropogon* with a small, fine-leaved *Paspalum* (*P. hyalinum*). The new froghopper was entirely confined, both as nymphs and adults, to this *Andropogon* zone, though its only host-plant was *Rhynchospora barbata*, which extended abundantly into the *Trachypogon* zone. This would appear to be another instance of a Homopteron attached less to a botanical species than to a definite plant-association, determined in this case apparently by position on the moisture gradient from stream bed to dry savannah. Mr. Pickles later found this in a small edaphic savannah near Pará.

T. flavilatera itself was found by Mr. Vesey-Fitzgerald at the same station, at about 6,300 feet on the slopes of Roraima, thus just outside the British limits. Few nymphs were present, but the host-plant seemed to be the same sedge (*R. barbata*) growing in savannah with *Paspalum contractum*, *Trachypogon plumosus*, *Lagenocarpus* sp., and a curious twisted leaved Bromeliad, all growing under slightly drier conditions than those favoured by the little *Tomaspis rhynchosporae*, so that, though occurring within a few yards of each other, their respective ranges did not overlap.

Clastoptera spp. were often plentiful on the small savannah tree (*Byrsonima crassifolia*), on the bush (*Bauhinia* sp.) fringing bush-islands, and on an unidentified swamp shrub.

(vi). *Froghoppers on the Lower Amazon*.—No fewer than 12 species of *Tomaspis* occur, often in exceedingly heavy infestations, on the Amazon below Manáos. They have been the subject of intensive ecological research by Mr. Pickles, who accompanied me on my latest expedition to Brazil. The following notes, in some cases concerning species which he did not encounter, but otherwise serving as an introduction to his more specialised account, are based chiefly on my own observations and dissections. Three of these species are savannah forms, while of the remainder, two at least attack sugar-cane and four others are attached to the wide riparian grass-zones of *Echinochloa polystachya* and *Paspalum fasciculatum*, one of them forming on the latter grass tremendous mass-infestations high up on the stems.

One of the most interesting of the savannah forms is a large pale brown *Tomaspis* (*T. terrea*) occurring in the clumps of a tall, but fine-leaved, razor-grass (*Paspalum pleostachyum*) on the moister campos of Marajó Island. The spittle, viscid like that of *T. pubescens*, is placed low down in the clumps, with often several nymphs in one mass. It was common also on another, less abundant razor-grass, *Paspalum densum*, while an empty spittle-mass on *Axonopus compressus* also belonged probably to this species. At least half the spittle-masses in clumps of *Paspalum pleostachyum* were placed in nests of soft moist earth built up among the grass-blades by the fire-ant (*Solenopsis saevissima*) which streamed out and stung viciously. This curious association is probably based on a habit of the adults of laying their eggs in the damp earth of these nests, rather than in the harder soil. The nymphs would be protected by the spittle, but it is difficult to understand why adults are not attacked.

A second savannah species (*T. picklesi*) was discovered by Mr. Vesey-Fitzgerald on the Santarem campos already described. It was attached chiefly to a small grass, *Paspalum carinatum*, and its biology was studied in detail during several months by Mr. Pickles.

A form superficially resembling *T. flavilatera* of British Guiana was locally abundant on roadside grasses in second-growth rain-forest between Pará and Vigia.

It is *T. incompleta*. The chief hosts were *Paspalum conjugatum* and *P. plicatulum*, often growing with much *Xyris* sp. and *Dichromena ciliata*, in an association very similar to that affected by *T. saccharina* in Trinidad. Large numbers of nymphs and adults were dissected by Mr. Vesey-Fitzgerald and myself, and later the infestation was studied by Mr. and Mrs. Pickles.

At Fordlandia I found *Tomaspis incompleta* on *Paspalum conjugatum* growing amongst Johnson and Bermuda grasses near the houses. Mr. Pickles obtained much more material there in the wet season. *Tomaspis rubra* and *T. pubescens*, in second-growth bush and on *Paspalum conjugatum* in rain-forest clearings respectively, were also found at Fordlandia.

The only other Amazonian *Tomaspis* which need be mentioned here is the species (*T. morialis*) which was so phenomenally abundant on *Paspalum fasciculatum*. The infestation was sometimes practically 100 per cent. The adults clustered in the leaf-funnels of this tall stout grass, just as in cane, while the nymphs fed at a considerable height up the stems. The same species was found about 20 miles up the Rio Branco. It was especially abundant between Santarem and Manáos. Very large numbers of nymphs and adults were collected.

(vii). *Froghopper (Tomaspis) not found in Haiti*.—In the preliminary report (p. 112) it was mentioned that no froghoppers of this group could be found in five weeks' intensive search. The work on *Diaprepes* parasites gave me a further opportunity to search in Haiti during the more favourable conditions of the wet season. Very promising and luxuriant associations of *Paspalum conjugatum*, of *P. distichum*, of Guinea grass, of *Paspalum virgatum*, of *Axonopus compressus*, and of lush, fine sedges, were examined without success, in the neighbourhood of Port-au-Prince, the southern peninsula, the interior, Cap-Haitien and La Gonave Island.

(viii). *The froghopper position in Trinidad*.—As with *Castnia*, so with *Tomaspis*, the economic position has changed radically since my preliminary report. In that (p. 106) I apparently wrote too optimistically of the favourable effects of liming, while the statement that dusting with calcium cyanide is a satisfactory method of control has not been borne out by continued practice, and attempts in this direction have now been given up. It thus appears that, while the intensive ecological data accumulated under the auspices of the Sugar Cane Investigation Committee are bound in the long run to assist very materially in the problem of control, the prevention of outbreaks is still outside our powers. The discovery of an efficient nymphal parasite still offers the most hopeful possibility of complete control, and it is hoped that the Committee will continue to support the search until this is found.

I say "nymphal" parasite advisedly, since it seems to me that little is to be hoped from egg-parasites, for reasons additional to those considered on p. 185. In the first place, we have already working in Trinidad no fewer than 4 egg-parasites whose rate of parasitism ("the highest average figure for the whole area"—Pickles, 1933 a, p. 233) is at the most about 5 per cent., the eggs laid in the soil, and comprising the vast majority, being practically immune. In the second place, the well-developed adaption of *T. saccharina* to the cane-field environment is nowhere exemplified better than in its habit of inserting most of the eggs into the soil, where they resist the almost arid conditions of the dry season and are at the same time almost completely sheltered from the attacks of the small and delicate egg-parasites. It is possible that the high intrinsic mortality in these eggs, sometimes amounting to 100 per cent. (Pickles, 1932 a), is an indication that this adaption is by no means perfect, but it is certainly far more efficient than anything the froghopper parasites or predators have yet been able to achieve, and it remains the crux of the froghopper problem, which will have either to be solved by direct methods or avoided by the utilisation of a nymphal parasite.

I have already pointed out (Prel. Report, p. 110) that we need a parasite which could adapt itself to these conditions, and I have suggested that a form from a monsoon-forest fauna would probably be suitable. Inspired by the discovery of several species of savannah froghoppers, adapted to an even longer and more severe dry season, Pickles has now suggested that a parasite of these would perhaps be successful in Trinidad cane-fields, and this remains a very promising possibility. The papers of Pickles (1933 *a, b*) supply a valuable summary of the investigation in Trinidad, the details being recorded in the Minutes and Proceedings of the Sugar-cane Investigation Committee.

(ix). *Summary of parasites and regular predators of Tomaspis.*—In Trinidad the known egg-parasites are: *Paraphelinus tomaspidis*, *Oligosita giraulti*, *Abbella tomaspidis*, *Anagrus urichi*. Of these only the last seems to be a regular parasite of froghopper eggs. It is certainly the only one of present economic importance. Regular insect predators, so far as we know, are confined to the Syrphid flies of the genus *Salpingogaster*, two species in Trinidad, *S. nigra* and *S. pygophora*, the latter believed to be confined to *Tomaspis rubra*, and the former specialising very largely on *T. saccharina*.

Williams' list (1921, pp. 65-93), of other parasites and occasional predators, including fungi, *Mermis* worms, insects, Arachnida, Amphibia, reptiles and birds, has been little augmented. Vesey-Fitzgerald (1933, p. 211) has found that "froghoppers form a considerable proportion of the food" of four species of cane-dwelling frogs, *Leptodactylus typhonus* and three *Hyla* spp.

In Cuba a Nematode worm and the predator *Salpingogaster punctifrons* have been recorded. In Jamaica a *Salpingogaster* is known to attack *Tomaspis* nymphs.

Salpingogaster nigra is widely distributed in South America, extending as far south as São Paulo (specimens collected by Dr. C. H. T. Townsend). On the present investigation it was found frequently in the Kanuku Mountains of British Guiana. On the Lower Amazon, a larva not uncommon near Pará probably belonged to this species. Williams records it in the North-West District of British Guiana, in Tobago and in Costa Rica. In the Kanuku Mountains, in association with the same species is a much rarer pale yellowish-brown form, not yet determined. Williams (*op. cit.*, p. 66) has recorded an egg-parasite (*Anagrus* sp.) in Panama and Mr. Pickles found evidence of one on the Lower Amazon.

The discovery of a *Tomaspis pubescens* adult in the Kanuku Mountains, with a white Phasiine (Tachinid) egg plastered to one tegment, added a member of a widely different group of efficient parasites to the list of those attacking froghoppers. Unfortunately no further material could be found, in a lengthy search in an abundant infestation, and the writer was inclined to ascribe this solitary occurrence to an aberration of instinct; but Dr. W. R. Thompson is more optimistic and believes that a further investigation should be made.

(d) *Cane Root-borer* (*Diaprepes abbreviatus*).

I mentioned in the preliminary report a study of *Tetrastichus haitensis*, a Chalcid egg-parasite of a related species in Haiti. The average percentage of parasitism, by a clerical error, was reported (p. 116) as 6 per cent. instead of 64.

In June 1931 further preliminary studies were made in Haiti with a view to introducing this very promising parasite into Barbados. During July and August five shipments were sent from Haiti and one, very large, from Porto Rico, where this parasite attacks *Diaprepes abbreviatus* itself in the cane-fields. Most of the Haitian collections in eggs of the related weevil, *Prepodex quadrivittatus*, were made from leaves of papaya in mixed cultivation (with some sugar-cane). Parasitism of a given attacked egg-mass varied from 25 to 100 per cent. Usually it was 100 per cent. As many as 65 adults were reared from one egg-mass on *Ipomoea crassicaulis*, and from

a second on the same host-plant, 58 were obtained. The numbers from papaya were smaller—13 to 38.

In Puerto Rico Mr. H. T. Osborn had found not only *Tetrastichus haitensis* but also a giant Trichogrammatid, *Ufens osborni*, Dozier, attacking the eggs of *D. abbreviatus*. In August the latter was found so rare as to be unobtainable, but rich collections of *T. haitensis* were obtained for a sixth shipment to Barbados, chiefly from a line of fig trees growing in the midst of extensive cane-fields at Aguirre. Some material was collected from leaves of seedling grape-fruit at Santa Isabella, where it was parasitising *D. abbreviatus* eggs to the extent of nearly 90 per cent. (estimated).

Mr. Tucker reared the material under laboratory conditions in Barbados, finding that the Puerto Rican race seemed much more vigorous and promising than the Haitian one. He made extensive liberations and later obtained further material from Dr. Wolcott in Puerto Rico, but so far no recoveries have been made (Tucker, 1933 a).

(e) *Hardback Beetles* (Scarabaeidae).

These are a serious cane pest, chiefly in Barbados and in British Guiana. I have not been actively concerned with the position in Barbados, which has been studied and summarised by Mr. Tucker (1932), but in British Guiana the pest is attracting increasing attention (especially on the East and West Coasts) and there have been frequent and repeated requests for some attempt at biological control. A search for parasites of these beetles has therefore been included in the future programme. An admirable summary of our present knowledge, embodying much original research, has been prepared by Mr. Cleare (1933) and will serve as a basis for preliminary studies. More detailed local ecological research will be essential before any actual introductions are contemplated. It is a paradoxical fact of great economic importance that flood-fallowing, which is in itself an excellent measure of control, yet leaves the field in a condition highly attractive to the beetles and thus liable to speedy re-infestation.

The chief injurious species in British Guiana are *Lygyrus ebenus*, *Dyscinetus geminatus* and *D. bidentatus*. Natural enemies already known in the colony include several birds, the large toad (*Bufo marinus*) already known as an efficient predator in Puerto Rico, whence it has been introduced into Hawaii, two Scoliid wasps, *Tiphia parallela* and *Dictis dorsata*, and an Asilid, *Mallophora calidis* (larvae attacking the grubs). Also the green Muscardine fungus, *Metarrhizium anisopliae*, is of common occurrence. According to Mr. Cleare none of these checks has been sufficiently studied in British Guiana.

It has been pointed out that further parasites may be sought both on the mainland and in the Greater Antilles (Santo Domingo being especially promising) during the course of exploratory work on other projects.

(f) *Cane Aphis* or "*Lice*" (*Sipha flava*).

Like hardbacks, cane aphis is attracting increasing attention in British Guiana, especially in Berbice, and there have been many requests for biological control measures. This seems to me a very hopeful project since an examination of 17,000 examples in Berbice, in February 1933, showed no sign whatever of parasites. The local predatory insects (chiefly the ladybirds, *Neda sanguinea* and *Megilla maculata*, and the Syrphid fly, *Ocyptamus dimidiatus*) which already attack it (Cleare, 1928) are probably insufficiently specialised to effect general control. There is decidedly a niche for an efficient parasite. The apparent absence of parasites, coupled with its only recent increase to importance, the first outbreak having been recorded in 1927, suggest that the cane aphis is an introduced insect in British Guiana. In Puerto Rico, which significantly enough is one of the few other neotropical countries where serious outbreaks are recorded, Oben (McConnie, Oben and de Celis, 1932, p. 53), believes it was introduced with the Uba cane. The theory of introduction implies

the possibility of future increase and spreading, which is already exercising the mind of the planting community.

(g) *Minor Cane Pests.*

(i). *Metamasius* spp.—The important secondary weevil pest of cane, *Metamasius hemipterus*, which often increases greatly the damage caused by *Diatraea*, *Castnia* or rats, in bad infestations, and also follows *Castnia licoides* in banana pseudo-stems, was traced to a primitive habitat in the swamp-forest of the Orinoco Delta, where the larva was boring in the mechanically injured top of a young buba palm (*Iriartea exorrhiza*). In the rain-forest at the base of the Kanuku Mountains the same species was attacking wild bananas. At Fordlandia on the Tapajoz it seemed to be absent even from cane which was heavily rat-injured. Mr. C. E. Pemberton informs me that a Tachinid fly parasite of *Metamasius* is known in Mexico (Sinaloa). This fly, *Myiophasia metallica*, Townsend, was introduced into Hawaii in 1923 to attack the Hawaiian cane-borer (*Rhabdocnemis*), but failed to become established (Swezey, 1925, p. 376).

(ii). *Leaf-eating caterpillars.*—*Laphygma frugiperda* and *Mocis repanda* larvae are occasionally locally injurious to cane in Trinidad and British Guiana. In March 1933, under dry conditions, the former was shown to me by Mr. Cleare inflicting very great damage on the coastal pastures. I examined a mass outbreak in an original plant-association on the Lower Amazon. It was attacking young growth of the grass, *Luziola spruceana*, springing up in the drying bed of a lagoon, which it occupied to the exclusion of every other plant. The vast plain, about 15 miles in diameter, resembled a huge field of young wheat. Dissection of large numbers of the larvae revealed no parasites, but the infestation was young (as evidenced by the absence of pupae and full-fed caterpillars), and would have been more interesting in another month. Here is a pest primitively attached to a wild monoculture of great extent—since these lagoons fringe the Amazon (not to mention its tributaries) for hundreds of miles.

In Cuba two Tachinids, one of which has been determined as *Archylas basifulva*, were reared from *Mocis disseverens* attacking guinea-grass (*Panicum maximum*).

(iii). *Auximobasis obstricta*.—A small speckled larva found on two occasions boring young cane shoots in the Valley of Caracas changed into a shining, smooth, squat pupa, half the size of *Diatraea saccharalis*, and finally gave emergence to this moth.

2. Cacao Pests.

The very serious depression has rendered it difficult to keep up the standards of cultivation of cacao, and this has apparently affected the pest-situation adversely, at the same time that it has put out of court expensive *ad hoc* control measures. Biological control is needed more than ever. Unfortunately, as the arrangement of this report will show, the investigation, in response to strong representations by the sugar industry, backed by very considerable financial assistance, has tended towards an increasing concentration on sugar-cane insects, with a corresponding enforced neglect of other crops, including cacao.

Cacao thrips (*Heliethrips rubrocinctus*).—Possibly owing to lowered standards of cultivation, but also encouraged by unusual weather conditions, there has been a serious outbreak of thrips in many parts of Trinidad. No new local parasites have been discovered, nor could the pest itself be found in the northern Venezuelan cacao districts, or in the stand of wild forastero cacao discovered in the Kanuku Ranges of British Guiana (Myers, 1934 d). The investigation has thus been greatly handicapped by shortage of material for study.

It is hoped later to investigate the Scelionid egg-parasite, *Baryconus*, reported from Bahia, while the study and introduction of *Dasyscapus* from West Africa has

again been advised. There is now the possibility of air transport to solve the problem of importation.

In the meantime another parasite—this time of the nymphs—has been reported from Costa Rica (Kaden, 1934, p. 148), but no material was reared for determination. It should certainly be investigated.

A second visit to Jamaica enabled the promising predacious bug found in 1930 to be studied further, and adults were eventually reared, which proved to be small, clear-winged Mirids, of a new genus and species. Like the nymphs, the adults feed on the cacao-thrips.

Cacao Beetle (*Stirastoma depressum*).—Here again the investigation has been greatly hampered by scarcity of material in the regions visited, so that we still know far more parasites in Trinidad, where we wish to control it, than have been recorded elsewhere. Data on the Hymenopterous parasites has been summarised elsewhere (Myers, 1932*a*, pp. 127–128, fig. 3). A Tachinid parasite, as yet undetermined, has also been discovered in Trinidad. Collecting by hand and trapping adult beetles are still practised.

No *Stirastoma* was found in the cacao plantations of northern Venezuela or of the Lower Amazon. Patches of the favourite alternate host-plant, *Malachra alceifolia*, were examined at Ocumare de la Costa, and wide stretches of it on the llanos without discovering a trace of the insect. This plant is nearly always attacked—at least scarred by the beetles in Trinidad. Another preferred host, *Pachira aquatica*, was not seen attacked on the Lower Amazon. Between Santarem and Manáos a very small infestation on the tree, *Bombax monguba*, yielded no natural enemies.

It is possible that the cacao plantations about Tucupita, in the Orinoco Delta, would yield parasites suitable for Trinidad, for the beetle occurs as an indigenous insect in the forest of this region, nearer the British Guiana border. These plantations have not yet been visited.

3. Cotton Pests.

Cotton pests have been investigated even less than those of cacao, and there has been no opportunity, in the countries visited, to study any adequate infestations. The only cotton-insects occurring with any frequency throughout the regions visited have been the cotton-strainers (*Dysdercus* spp.).

Pink bollworm (*Platyedra gossypiella*).—In the preliminary report I emphasised the very marked and entirely puzzling cycles of abundance of this pest in the Lesser Antilles. In Montserrat, for instance, the infestation decreased from 93 per cent. in 1927, to 73 per cent. in 1928 and to less than 2 per cent. in 1929. This extraordinary decrease was general throughout the islands, and was variously attributed to clean-up campaigns, fumigation of seed, change of planting season, and the 1928 hurricane, but as I pointed out (p. 129) we were really entirely in the dark as to the cause. Our ignorance has been further emphasised by the fact that although measures of direct control have been employed with unabated vigour the infestation has again increased to serious proportions (*Trop. Agric.*, 1933, p. 23), in fact, in some islands (*e.g.*, Barbados) to an extent not experienced before. Plans have therefore been made for a thorough ecological study as a preliminary to parasite introduction. In the light of previous remarks on the qualifications of a parasite for boring insects (p. 186), the writer would strongly advise the investigation of a Tachinid parasite, such as *Tortriciophaga tortricis* recorded from Mexico. *Apanteles thurberiae*, a Braconid parasite of the pink bollworm in Trinidad, is worthy of further study. Since the preliminary report was published, the pink bollworm has been found for the first time in Jamaica (Kisliuk & Cooley, 1933, p. 2).

Cotton-strainers (*Dysdercus* spp.).—Pearson has lately (1932) made a very useful study of the Trinidad species. The writer has collected and dissected considerable

numbers of nymphs and adults in a great variety of plant-associations—chiefly Malvaceous hosts—on the mainland of South America (Guiana, Venezuela, Brazil, Colombia). The species have not yet been determined. An interesting infestation was seen on cabbage in a Venezuelan cultivation near Roraima, at an elevation of over 3,000 feet.

In my survey of *Dysdercus* parasites (Prel. Rept., p. 135) Dr. Wolcott has kindly pointed out that I inadvertently omitted probably the most promising of them all, namely, the Phasiine Tachinid (*Acaulona peruviana*), which at times heavily parasitises the cotton-stainers in Peru (Townsend, 1913, 1928).^{*} Steps should be taken to investigate this, with a view to introducing it into the Lesser Antilles.

Other cotton pests.—There has been no opportunity to make any further studies of the leaf-worm (*Alabama argillacea*). An unexpected infestation of black scale (*Saissetia nigra*) was examined on a few plants of cotton in an Indian clearing, very isolated in the rain-forest of the Pakaraima Mountains, at an elevation of about 1,400 feet.

4. Mahogany and Cedar Tip-borer (*Hypsipyla* spp.).

In Trinidad it is probable that the new silvicultural methods now employed, with the provision of tall shade, will result in greatly decreased damage by this pest to cedar (*Cedrela mexicana*) and crappo (*Carapa guianensis*). Mr. Urich has now reared *Hypsipyla* from the fruit of *Cedrela mexicana* in Trinidad. Further dissections have been made and three parasites have been reared additional to those recorded in the preliminary report (p. 139). These include an additional Tachinid, very distinct from the first, a red *Ipobracon*, and a curious large Chalcid (external parasite of the larvae). None of these is yet identified. In one series from crappo shoots at Arena, the rate of parasitism by the *Sarcophaga* was 6.25 per cent. A larger lot from *Cedrela* shoots at Tamaná showed a parasitism of 12.2 per cent. by the Chalcid and the *Ipobracon* combined. A large collection of larvae from dropped seeds of crappo collected in virgin forest between Guayaguayare and Moruga were parasitised at a very low rate (10.62 per cent.) by a Tachinid.

As with *Stirastoma*, so with *Hypsipyla*, we now know many more parasites already working in Trinidad—seven species, if we include the fungus, *Cordyceps*—than have been recorded elsewhere.

In northern Venezuela I was informed by Dr. H. Pittier that a new plantation of *Cedrela mexicana* at Caracas was severely attacked by *Hypsipyla*. I saw no infestation in the roadside trees. At San Juan de los Morros, in Dr. Dolge's gardens, local *Cedrela* of the same species was badly damaged, while adjacent young trees of the same age of West Indian mahogany (*Swietenia mahagoni*) and Venezuela mahogany (*S. candollei*) were not attacked. In its relatively quick growth and timber characteristics, Venezuelan mahogany is intermediate between the West Indian and the Honduras species, but in resistance to *Hypsipyla*, amounting almost to immunity, it resembles the first, and is therefore worthy of more extended cultivation.

In British Guiana *Hypsipyla* was badly attacking young Honduras mahogany planted in the North-West District. On the other hand, West Indian mahogany and local *Cedrela* growing in the Residency garden were unattacked in spite of a heavy infestation in *Carapa* seeds just over the fence.

In the Lower Amazon, the seeds of *Carapa guianensis*, there known as andiroba, are an important article of trade, for the sake of the oil. Huge piles on a wharf near Pará showed a very heavy old infestation by *Hypsipyla*, many of the seeds being mere shells.

At Miami, Florida, in the garden of Dr. David Fairchild, in May, the young tender bronzy-green spring leaves of West Indian mahogany were in many places bundled

^{*} Townsend mentions that this is attacked by a hyperparasite, *Perilampus* sp.

and webbed together by the larvae of *Hypsipyla*, forming the only considerable infestation I have ever seen on this usually resistant species, and recalling the type of damage frequent on *Cedrela toona* in India. Occasionally the extreme tip or growing-point of the shoot was bored or rather slightly excavated, but most of the damage was external. Only two larvae were found, large and in the blue stage (final instar), and these were flaccid and either dead or very completely paralysed. They were in the first stages of parasitism by *Microbracon cushmani*, which adds a promising new member to our list of parasites.

5. Arrowroot Leaf-roller (*Calpodex ethlius*).

Since the publication of the preliminary report this pest has been the subject of research in Trinidad and St. Vincent by Mr. Ulrich, and in St. Vincent by Mr. C. K. Robinson, lately of the Trinidad Sugar-cane Investigation Committee (Ulrich, 1932).

In Cuba a very important egg-parasite, sometimes killing 100 per cent. (L. C. Scaramuzza), is *Xenufens rushini*.

In the Kanuku Mountains, on feral bananas, I found a Hesperiid leaf-roller very nearly allied to *C. ethlius* heavily attacked by a Tachinid. In one case the parasite larvae were easily visible through the transparent skin of the caterpillar, but they were flattened almost to circular discs by the pressure of the greatly distended gut, full of leaf-tissue. By manipulation of the living host they could be moved from one end of its body to the other.

The known parasites may be summarised as follows, beginning with those already present in St. Vincent:—*Trichogramma minutum* (Harland); an undetermined egg-parasite (Harland, 1916); *Elachertus meridionalis*, larval parasite (Ulrich); *Eucelatoria australis* (TACHINIDAE), larval parasite attacking also *Alabama argillacea*, the cotton leafworm (Harland, 1917); *Sarcophaga* (*Sarcodexia*) *sternodontis* (Harland, 1917); an undetermined Tachinid (Harland, 1917); *Apanteles* sp. (C. K. Robinson), a solitary larval parasite; *Brachymeria annulata* (C. K. Robinson), a pupal parasite.

In Trinidad:—*Trichogramma minutum* (Ulrich, Myers), egg-parasite; *Ooencyrtus* sp. (Ulrich), egg-parasite; *Anastatus* sp. (Ulrich), egg-parasite; *Apanteles talidicida* (Ulrich), a larval parasite originally described from a Hesperiid, *Talides sergestus*, feeding on *Heliconia* in British Guiana and reared by Box, and in Trinidad also attacking a third Hesperiid, *Larema accius*, on *Canna* (Ulrich); *Microbracon* sp. (Ulrich), larval parasite; *Achaetoneura nigripalpis* (Ulrich), larval parasite; *Exoristoides urichi* (Ulrich), larval parasite; a third and undetermined Tachinid (Myers). Hyperparasite: *Spilochalcis* sp. attacking the *Apanteles* (Ulrich).

In British Guiana:—*Holcencyrtus calypso*, egg-parasite (Crawford); *Elachertus meridionalis*, larval parasite (Crawford), which was erroneously listed as an egg-parasite in my preliminary report (p. 114).

In Cuba:—*Xenufens rushini* (Scaramuzza), egg-parasite; an undetermined Tachinid (Myers), larval parasite; *Elachertus meridionalis*, larval parasite (Myers). Hyperparasite: *Aphaereta apicalis*, attacking the Tachinid.

In Porto Rico:—*Trichogramma minutum* (Wolcott), egg-parasite; *Chalcis incerta* (Wolcott), pupal parasite.

6. Sweet Potato Weevil or Scarabee (*Euscepes batatae*).

In the regions visited this insect was sought much more often than it was found. Sweet potatoes of Indian provision-patches in the interior of Guiana were apparently not attacked. The only considerable material, yielding abundant larvae for dissection, was bought in the market at Santarem, Lower Amazon, and was not parasitised.

7. Coconut Pests.

Very little attention has been paid to coconut insects. In Antigua, in August 1931, I saw a very heavy infestation of *Aspidiotus destructor* on old, tall coconuts, the leaves of which were yellowed, or grey, and almost dying from the effects. If the economic situation ever warranted it, the ladybird, *Cryptognatha nodiceps*, could be introduced from Trinidad.

8. Banana borer (*Cosmopolites sordidus*).

In April 1933, a second survey was made in association with Mr. W. H. Edwards, Government Entomologist, of the status of this pest in Jamaica. Recommendations were made that a new parasite (not a predator) should be sought in New Guinea. Stands of wild bananas and of wild plantations in the Kanuku and Pakaraima Mountains of British Guiana were examined for *Cosmopolites* without success (Myers, 1934 d). An earwig predator, not yet identified, was found not infrequently in Jamaica. In Puerto Rico, *Cosmopolites* is spreading rapidly (Leonard) owing to the great extension of bananas as temporary shade for coffee after the recent hurricane. Leonard (1931) has compiled a very valuable bibliography of *Cosmopolites*.

9. Coffee Pests.

In the important coffee cultivations of northern Venezuela insect pests are present in entirely negligible proportions. Elsewhere some attention was paid to coffee in Jamaica and in Haiti. The introduction of the citrus black-fly parasite into Jamaica (see below) has benefited coffee, since this crop is also attacked.

In Jamaica and Haiti, as in northern Venezuela, the leaf-miner (*Leucoptera coffeella*) is insignificant as a pest, and it was very difficult to obtain sufficient material for study. This scarcity in Jamaica prevails especially in the higher levels, where, of course, the best coffee is grown. It would be worth experimenting in St. Lucia with nurseries placed at a high elevation, since there it is the young plants which are so ruinously attacked. I found more material at the Hope Gardens, where coffee is grown out of its commercial range. These larvae were attacked to the extent of 62 per cent. by an external Chalcid parasite, pupating (black, flattened and rather slender) nakedly in the leaf-mines. It has not yet been determined.*

10. Citrus Pests.

Black-fly (*Aleurocanthus woglumi*).—I had seen something of the work of this pest in Cuba in 1925 and again in the course of the present investigation, in 1929, 1930 and 1932. In April of the latter year I was so impressed with the speedy and sweeping results of the parasite (*Eretmocerus serius*) introduced into Cuba from Malaya by the Cuban and United States Governments, co-operating, that, with the collaboration of Mr. W. H. Edwards in Jamaica, I decided to introduce it into that island. The Cuban Government gave me most generous facilities and material aid.

Before the advent of this parasite, expensive spraying programmes were in operation in Cuba and in spite of them the black-fly was increasing from year to year. Whole plantations showed scarcely a green leaf. In April, when the parasite campaign was nearing completion, at least in the Central districts, I visited many farms and citrus plantations and was astonished at the rapidity with which the parasite was working. Citrus blocks on which *Eretmocerus* had been liberated six months before were our best collecting grounds for parasitised material. Those which had received the parasite nine months before were usually completely cleared. These huge and effective populations were all derived from 12 individuals which survived the journey from the Far East.

* [Twelve parasites of *Leucoptera* have been received by the Imperial Institute of Entomology from East Africa.—ED.]

Natural propagation was so rapid that artificial rearing previous to liberation soon became unnecessary, and neither this nor sleeving was used in Jamaica. Mr. Edwards received and distributed the single large shipment which I sent from Havana in April 1932. Recoveries were made in July. In April 1933, with Mr. Edwards, I visited the sites of some of the original infestations. Lime trees at Hope showed a heavy two-foot growth of new green shoots such as they had not known for years. It was hardly possible to find a black-fly; in fact, Mr. Edwards had made a standing offer of one shilling for every black-fly found on these trees. From these it had spread to a distance of at least two miles and already achieved control there, as it had done also at considerable elevations in the coffee lands of the Blue Mountains. There is every prospect of very complete control in the near future.

Eretmocerus serius was introduced into New Providence, Bahamas, in October 1931, recovered two months later, and was already doing good work at the time of my visit in May 1932. Into Haiti Dr. Dozier introduced it in August 1931. For the history and technique of these various introductions see Clausen & Berry (1932), Edwards (1932) and Dozier (1932).

Stingless bees (*Trigona*).—These (*Trigona silvestriana*) are serious pests of the thriving grapefruit industry of Trinidad. A short study has been published elsewhere (Myers, 1934 g). Unfortunately none of the extensive series of nest-parasites and inquilines discovered has yet been identified, and attempts at control are necessarily so far confined to direct measures of destroying nests, and spraying with deterrents or with poisons. Similar bees are injurious to citrus cultures in British Guiana, British Honduras and Venezuela.

Other citrus pests.—New and extensive grapefruit cultures in the north of Haiti were badly infested with fire-ants (*Solenopsis geminata*); 20 per cent. of the young trees were said to have been destroyed. For this the method of cultivation was, I think, almost solely to blame. Every young plant was elevated on a considerable mound to avoid foot-rot. Since the intervening flat ground was rather low, becoming very wet during the recent phenomenal wet season, and kept entirely bare of weeds, the ants were practically restricted, both for food and nesting-sites, to the grape-fruit mounds, most of which had a colony, whose members ate deeply into the bark, occasionally ring-barking the tree, and in other cases killing it more slowly. Crude castor-oil of local manufacture was being used as a deterrent, but we found ants burrowing in soil caked with this thick liquid. The bare weeding is certainly a mistake, and I was informed by the foreman that when pineapples are grown between the grapefruit the ant-nuisance is greatly abated, the ants being attracted, I believe, by the rather numerous mealy-bugs.

There has been some damage from this ant in Trinidad and also in Grenada.

The possibility of biological control by orthodox methods seems to me very remote, since we know no really effective parasites of ants. There does seem, however, to be great promise of control by manipulating the ecological succession (*cf.* p. 214) of ant-species which take possession of clearings in the tropics. In nature, particularly vicious and destructive ants like *Solenopsis* are often replaced by relatively innocuous species. Unfortunately these latter, even when innocent of direct damage, are often addicted to fostering highly injurious scale-insects, though not more so than *Solenopsis*. The whole question needs close study before any practical application can be made.

Scale-insects (COCCIDAE).—I have already mentioned the relative freedom from scales of citrus cultivations in the interior savannahs of British Guiana, apparently due to the transport difficulties which largely necessitated the bringing in of seeds rather than plants. In the large-scale cultivations developed at great speed by the Ford interests on the River Tapajoz these difficulties were completely overcome and abundant plant-material was brought in, already infested with most of the more

injurious citrus pests, which would otherwise have been absent from this very isolated forest-clearing.

In view of the widespread and successful development of the grapefruit industry I must again point out that, with the probable complete control of the blackfly (*Aleurocanthus woglumi*) by *Eretmocerus*, the green scale (*Coccus viridis*), which is a comparatively recent introduction (see Prel. Rept., p. 148), remains undoubtedly the gravest actual or potential pest of citrus culture throughout the West Indies. It may also become a serious pest of coffee. The possibility of introducing already known and apparently effective parasites of this scale from the East should be seriously considered.

11. Insect Pests carried in Steamers.

So many of the most injurious insects of the West Indies have been introduced, especially from the East, that a voyage from Trinidad to Cuba on a rice-ship just arrived from Rangoon was made an opportunity to study the insect fauna of a cargo from the East. Some 42 species of insects and Arachnids were found actually living and breeding on the ship, in spite of fumigation before leaving the East and in Trinidad on arrival. Many of these were injurious species.

12. Insects affecting Live-stock.

Some attention has been paid to these in Guiana (Myers, 1934 c), in the form of incidental observations while travelling in the interior. *Chrysomya americana* was found to cause abundant myiasis in the interior savannahs, and probably the same species in the forested areas infested wounds on bullocks made by vampire bats (*Desmodus*). Stretches of forest were found to be effective barriers to the spread of the house-fly (*Musca domestica*), which, abundant in the savannahs, has greatly extended its range in the tracks of the Boundary Commissions. Horse-flies (TABANIDAE), important as suspected carriers of mal de caderas, were found to be very definitely restricted in their distribution to different types of vegetation.

13. Miscellaneous Insects.

Wild pine-apples (*Ananas sativus*) in the Pakaraima Mountains were found on one occasion considerably infested by a caterpillar apparently identical with *Tmolus echion*, which is a pest of the cultivated fruit in Trinidad (Harris, 1927).

The cutworm, *Prodenia ornithogalli*, is a frequent pest of vegetables and tomatos in the Lesser Antilles. Mr. W. E. Howell, the Agricultural Instructor of Nevis, in January 1931, reported a considerable outbreak on tomatos in that island, and sent a reared parasite which he said was killing fully 75 per cent. towards the end of the infestation. At the request of the Commissioner of Agriculture I examined the insects and found them to be *Euplectrus platyhypenae*, a rather general parasite of cutworms and army-worms.

Leaf-cutting ants (*Atta* spp.) are well known to rank among the most destructive pests of miscellaneous cultures in the American tropics, I was therefore interested in Manáos to see a garden (that of the English Country Club) which, it is claimed, has been kept relatively free from them by planting the ornamental small tree, *Melia azedarach*. When these plants were first introduced, the ants once were observed cutting their leaves. They afterwards disappeared from the neighbourhood of the trees and have hardly been a pest since. The formicifuge properties of this tree are said to be well known in Brazil, but controlled experimentation would be desirable. It is curious and perhaps confirmatory in this connection, that Johnston (1932, p. 63) mentions a Sudan locust (*Cyrtacanthacris tatarica*) which "has a wide range of host-plants and when pressed for food may become almost omnivorous," but it does not attack neem (*Azadirachta indica*), which is a close relative of *Melia*.

Products of other Meliaceae, e.g., crabwood or andiroba-oil (*Carapa guianensis*) and cedar-wood (*Cedrela* spp.), are well known for their insectifuge qualities. On the other hand Squire (1933) has tried *Melia azedarach* as a repellent against insect pests of stored rice and padi without result.

A request from Bengal through Dr. W. R. Thompson (Farnham Royal) for information on natural enemies of water-hyacinth (*Eichhornia crassipes*) which might be utilised to control this weed, received incidental attention during the other investigations. Considerable areas of *Eichhornia* were seen in Guiana and Brazil, but so far no extensive marks of insect attack have been observed.

In the Pakaraima Mountains (see p. 204) at an elevation of 2,000 feet near Ipišiau, a zone of bracken (*Pteridium* aff. *esculentum*) fringing the forest and separated from the savannah by a belt of grass (*Paspalum anceps*) was very largely defoliated, with only stumps of fronds remaining over large areas. Unfortunately the bites were old, and I could find none of the insects responsible; but the infestation is interesting in view of the movement in Australia and New Zealand to control this weed by means of natural enemies.

VI. PARASITES FOR THE WEST INDIES FROM THE OLD WORLD TROPICS.

Cuba has set a good example and won remarkable results in this enterprise by introducing (in co-operation with the United States) a parasite of the citrus black-fly from Malaya into Cuba, whence it has now been imported into Jamaica and the Bahamas (see p. 243).

Scattered through the preceding pages are recommendations for several projects of a similar nature which may be brought together here, under the name of the introduced pest-insect and the country where effective parasites are known or are suspected to occur:—

- (1) Cacao thrips (*Heliothrips rubrocinctus*), Gold Coast
- (2) Green scale (*Coccus viridis*), South India
- (3) Pink bollworm (*Platyedra gossypiella*), India and the Far East
- (4) Banana-borer (*Cosmopolites sordidus*), New Guinea

The possibility of effective parasites, to which thickness of canes would present no obstacle to parasitism, attacking *Diatraea* in the giant canes (*Saccharum robustum*) of New Guinea, is well worth investigating.

VII. SUMMARY OF RESULTS AND RECOMMENDATIONS.

1. The report covers a period of 3½ years actually spent in the field.
2. During this time 19 major pests have been studied, with special reference to their natural enemies and other limiting factors. The pests of sugar-cane have, however, received by far the most attention, partly because this is the most important crop throughout the region as a whole, and partly because the industry has made substantial financial contributions.
3. Advice has been given, on request, to local Governments, planters' organisations and individual planters, and schemes have been drawn up for intensive local research on cane-borers, on froghopper and on mongoose. The researches of the two investigators of the cane-borer (*Diatraea* spp.), under grants from the Colonial Development Fund, have been supervised so far as their technical aspect is concerned.
4. For the control of the small moth-borer (*Diatraea*) the most important pest of sugar-cane as a whole, the Cuba fly (*Lixophaga*) has been introduced (in collaboration with Mr. Box) into the Leeward and Windward Islands, and the Amazon fly

(*Metagonistylum*) into British Guiana (in collaboration with Mr. Cleare). Both these very promising parasites, the second of which was discovered during the course of the investigation, are now widely established.

5. A specific parasite is now needed for *Diatraea canella* in British Guiana and *D. impersonatella* in Trinidad. It is possible that experiments now in progress (in collaboration with Mr. Pickles and Mr. Cleare respectively) that *Paratheresia* will serve for the first and *Metagonistylum* for the second, but a highly specific parasite for *D. canella* remains greatly desirable.

6. A promising Tachinid parasite of the large moth-borer (*Castnia licoides*) has been discovered on the edge of the Orinoco Delta, and it is hoped to introduce it shortly into British Guiana and Trinidad cane-fields.

7. No introductions into Trinidad can yet be made until a survey of the borer (*Diatraea* and *Castnia*) position has been carried out. This is now being undertaken by Mr. Pickles, under the auspices of the Sugar Cane Investigation Committee and in collaboration with the writer.

8. The Trinidad froghopper (*Tomaspis saccharina*) remains a pest of the first order, despite the excellent ecological work already done on it. An apparently promising Tachinid parasite on a closely related froghopper in the Kanuku Mountains proved too rare to be immediately utilised.

9. In collaboration with Mr. Tucker, Government Entomologist, a very efficient egg-parasite (*Tetrastichus haitiensis*) was introduced from Haiti and Puerto Rico into Barbados. In spite of very extensive breeding and liberation by Mr. Tucker, no recoveries have yet been made.

10. The Anthocorid (not Capsid) predator on cacao thrips (*Heliothrips rubro-cinctus*) in Jamaica has been further studied. It is not considered so promising as *Dasyseipus*, which should be introduced from the Gold Coast.

11. Cacao beetle (*Stirastoma depressum*) still has far more known parasites already in Trinidad than elsewhere. A more effective one is needed and is still being sought.

12. The pink bollworm (*Platyedra gossypiella*) has again increased to serious proportions during the period under review, and biological control is earnestly desired. It is suggested that the most promising parasite to investigate is a Tachinid (*Tortriciophaga*) in Mexico. First, however, it is essential that an ecological survey of the pink bollworm situation be carried out in the Lesser Antilles.

13. The allegedly efficient Tachinid parasite (*Acaulonia*) of cotton-stainers (*Dysdercus*) in Peru should be investigated.

14. The mahogany shoot-borer (*Hypsipyla*), like the cacao beetle, already has far more parasites in Trinidad than elsewhere. Three more have been discovered in the island, and one new and promising one in Florida.

15. The arrowroot leaf-roller (*Calpodex ethlius*) has been studied in Cuba and in Trinidad, and a Tachinid parasite additional to the two found by Mr. Urich has been discovered in the latter island.

16. A new and apparently effective parasite of the coffee leaf-miner (*Leucoptera coffeella*) has been found in Jamaica.

17. The banana-borer (*Cosmopolites sordidus*) has been studied in Jamaica and elsewhere and no parasites found. It is recommended that a search be made in New Guinea.

18. Through the courtesy of the Cuban Government the writer was enabled to introduce into Jamaica the Malayan parasite (*Eretmocerus serius*) of the citrus black-fly (*Aleurocanthus woglumi*). This has been well distributed by Mr. Edwards, Government Entomologist, and is now widely-established.

19. A number of minor pests were studied when opportunity offered during other investigations and while travelling.

20. Twenty-two papers on the more technical aspects of the investigation have been prepared for publication during the period under review.

21. While the first report was concerned very largely with the preliminary survey in our own Colonies, the present contribution largely deals with exploratory work, the most useful result of which was the discovery of the Amazon fly parasite for *Diatraea*.

22. Three successful introductions have, however, been made, benefiting British Guiana, Antigua, St. Kitts, St. Lucia, Barbados and Jamaica, while three more, to serve British Guiana, Trinidad and St. Lucia, are already planned.

23. The main work for the future, however, consists in the search for new parasites for the froghopper, for *Diatraea canella*, cane root-borer, cacao beetle, pink bollworm, cotton-stainers and sweet potato weevil (*Eusecipes*), and this search must be prosecuted further on the mainland.

24. The importance of searching in primitive habitats has again been emphasised, and has been confirmed by the discovery of the Amazon fly and the Tachinid parasite of froghoppers.

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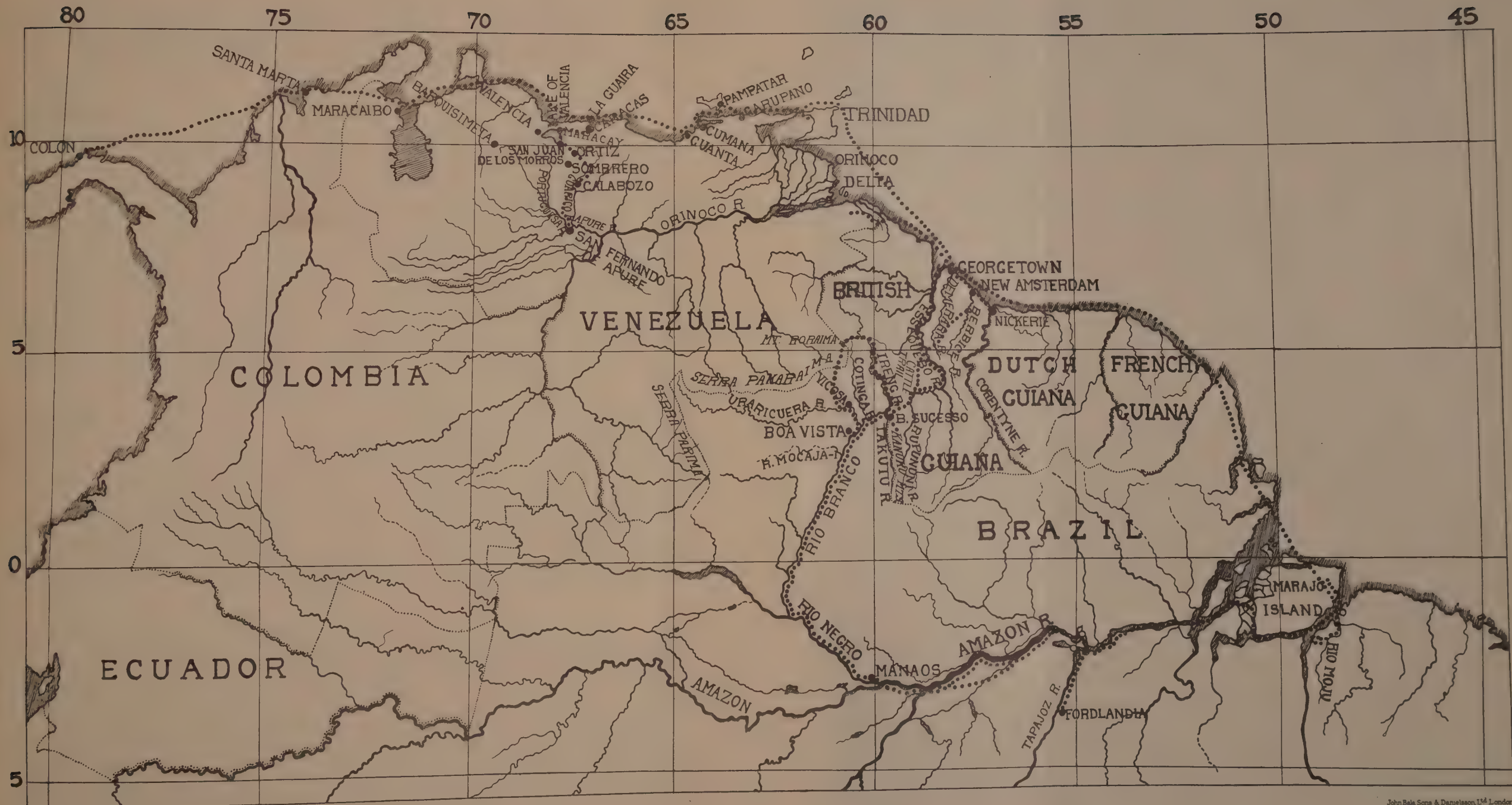
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NOTES ON *APANTELES SESAMIAE*, CAM., A PARASITE OF THE MAIZE STALK-BORER (*BUSSEOLA FUSCA*, FULLER) IN SOUTH AFRICA.

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South Africa.*

Introduction.

A survey of the parasites of the Maize Stalk-borer (*Busseola fusca*, Fuller) in the De Kaap Valley area of the Eastern Transvaal revealed the fact that there are three parasites which normally occur, namely, a Braconid, an Ichneumonid and a Tachinid. Of these, the two last-named are found only rarely at the early part of the summer and are obviously of little importance in the control of the pest. The Braconid, on the other hand, is common throughout the season and at times exhibits a high degree of control over the borer. This parasite has been identified by the Imperial Institute of Entomology as *Apanteles sesamiae*, Cam.

In 1933 a preliminary study of this parasite was commenced to assess its real value with a view to subsequent shipments to Canada for trial against *Pyrausta nubilalis*, Hbn. The following notes were accumulated during the course of this study and, although admittedly somewhat incomplete owing to the pressure of the writer's normal duties at the time, are presented here in view of the success which has attended overseas consignments.

In the description of the adult the wing terminology described by Wilkinson (1927) has been followed, and in the description of the larval mouth-parts and facial rods the terms suggested by Thorpe (1930) and Salt (1931) have been adopted. It is only comparatively recently that the significance of larval characters, and especially those of the head skeleton, in the determination of species in the parasitic Hymenoptera has been recognised, and in view of the importance of this branch of morphology it is highly desirable that some uniform system of nomenclature should be adopted. In many cases authors have shelved the question and have been satisfied to leave the future recognition of the head structures with which they were dealing to a few, often inadequate, illustrations. The lead given by Thorpe and Salt, therefore, is to be appreciated by workers on this group.

Description of the adult *Apanteles sesamiae*, Cam.

♀. Black, shining; palpi pale; scape, flagellum, tegulae and costal veins, fuscous, other veins testaceous; legs, including coxae, testaceous, the hind coxae black above; apical joints of tarsus slightly infuscated; 1st, 2nd, and 3rd tergites black.

Head: bearing only minute punctures; frons below the toruli markedly punctate and rugulose, shining and sparsely covered with short setae; clypeal area differentiated, not depressed below the level of the frons; facial depressions about midway between the apex of the clypeus and the eyes; posterior ocelli nearer to each other than to the eyes, the distance between them being slightly less than half that from them to the toruli; toruli above the middle of the eyes, situated closely together and a little more than the length of their own diameter from the orbital margins; vertex raised, smooth and shining, with a very few, minute and scattered setae; antennae with 16 to 17 flagellar segments which become shortened towards the

apex of the flagellum, the segments, except the apical one, a little longer than broad (5:4); flagellum densely covered with strong, straight hairs pointing apically, with four longer and stiffer hairs around the apical margin of each segment; rhinaria long and prominent. *Thorax*: mesoscutum strongly convex anteriorly, shining, with regular and rather coarse punctation which becomes more scattered and less marked posteriorly; mesoscutellum prominent, rounded, strongly carinate near the anterior margin, the carinae forming a curved row of rather prominent pits; metanotum short, depressed, about half the length of the mesoscutellum and with prominent median transverse carinae; parapsidal furrows well marked; propodeon (fig. 1) with a strong basal transverse carina and a longitudinal median carina, which is sometimes strong for the whole of its length, more usually basally strong to one-third of its length, then weak or absent; disk in the basal third smooth to rugulose, in the median third rugulose, and in the apical third rugose with strongly marked apical carinae, the sides of the disk with strong spiracular carinae; the whole thorax sparsely covered with short setae. *Wings*: forewings hyaline; the costal vein, stigma and metacarp, fuscous, the other veins testaceous; metacarp

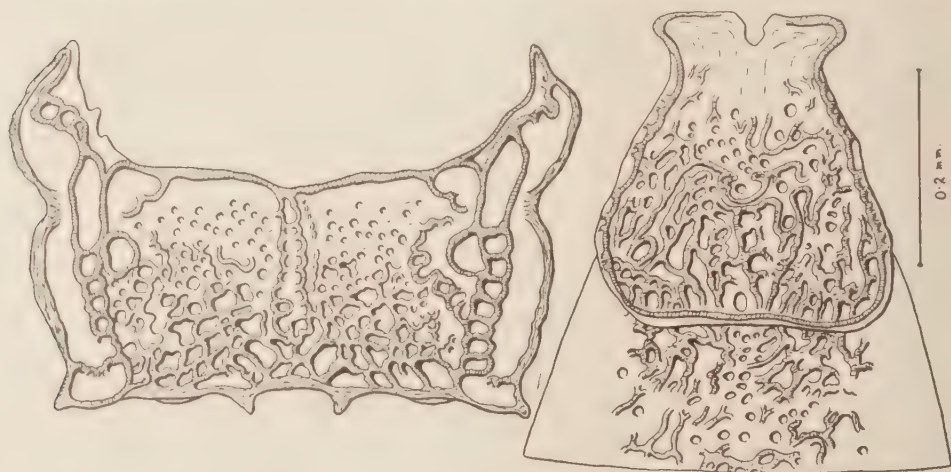


Fig. 1. *Apanteles sesamiae*, Cam., adult: propodeon and 1st and 2nd abdominal tergites.

only a little longer than the stigma; 1st transverse cubital a little longer than the 1st abscissa of radial, the latter being equal in length to the pigmented portion of the 2nd abscissa of cubital, which is twice as long as the pigmented portion of the nervulus; recurrent more than twice as long as the apical portion of the basal and half as long as the 2nd abscissa of medial; 1st abscissa of cubital about equal in length to the basal; nervus parallelus slightly pigmented for more than three-fourths of its length; hindwings hyaline; veins testaceous; metacarp shorter than the sub-costal and not reaching the apex of the wing; basal two-thirds of the 1st abscissa of medial unpigmented, the whole vein longer than the nervulus and about equal to the 1st abscissa of anal; the pigmented portion of the radial half the length of the nervulus and about equal to the pigmented portion of the 2nd abscissa of anal, which is short. *Legs*: hind tibial spurs equal in length and about half the length of the basal joint of the hind tarsus; hind coxae punctate basally above, smooth and shining below. *Abdomen*: 1st tergite (fig. 1) virtually smooth in the excavate basal third, except laterally where it is rugulose, weakly sculptured in the median third, except, again, laterally where it is strongly marked, strongly rugose in the apical third which is turned over and down; the median length

a little more than one-and-a-half times the basal breadth (11:6.5); somewhat narrowed immediately after the base, then gradually widening towards the apex, with the greatest width shortly before the slightly emarginate apex; the latter rather longer than the basal breadth (8:6.5) and narrower than the greatest width (8:11); the apical angles acute and rounded; 2nd tergite with the integument of the median area of the disk similarly marked to that of the apical portion of the preceding tergite, the lateral portions smooth; 3rd and succeeding tergites smooth and shining. Hypopygium obtuse and not extending beyond the apex of the abdomen; ovipositor sheaths short, about half the length of the hind tarsus. Length: 2.4 mm.

♂. Similar to ♀, with the same number of flagellar segments but with each segment longer, all except the apical one being three times as long as broad, thus making the whole antenna noticeably longer than that of the female.

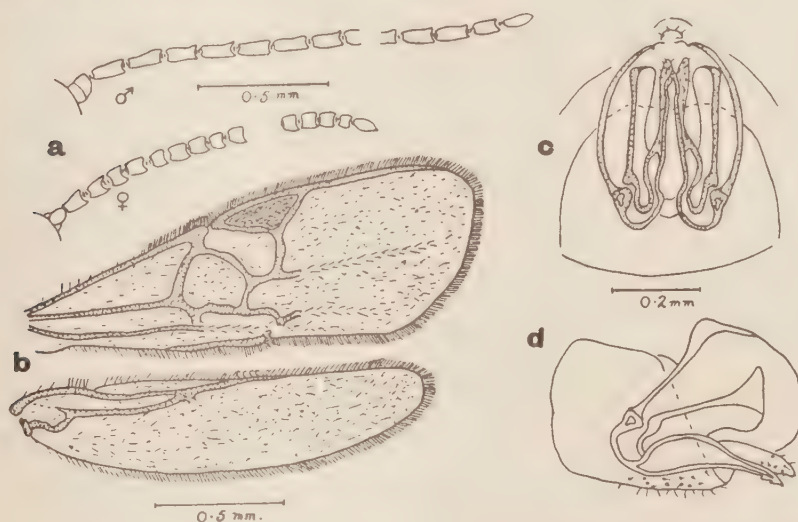


Fig. 2. *Apanteles sesamiae*, Cam., adult: a, antennae of male and female; b, wings; c, ventral; and d, lateral view of ovipositor and hypopygium.

Cocoons of white, thin, closely-woven silk, forming a tough, semi-transparent envelope. Normally produced in masses which are loosely bound together with strands of silk.

Morphology of the Last Stage Larva.

The fully-grown larva, on emergence from the host, is of the more usual elongate Braconid shape with the head and 13 post-cephalic segments clearly marked (fig. 3, a). It is approximately 2.5 mm. long, 0.73 mm. wide across the 9th abdominal segment, and tapers anteriorly to 0.33 mm. wide at the prothorax. In colour it is white and opalescent, with dark brown mandibles and facial rods. The cuticle is shining and translucent. A prominent hypopleural swelling is present on each side of abdominal segments 1 to 9 inclusive and on the metathoracic segment, each being ventral to the spiracles. Dorsal humps are very poorly developed on the median segments. A well-developed caudal vesicle is present on emergence from the host and persists until the final ecdysis immediately prior to pupation. The integument of the vesicle is found attached to the cast larval skin in the cocoon. The vesicle is semi-transparent, flattened and slightly concave at the posterior extremity and somewhat

resembles a funnel in appearance. The integument of the body segments is covered closely with very minute spines, giving the body a speckled appearance under low powers. The spines are short and broad. There is a row of setae on each of the post-cephalic segments. On the metathorax a group of four setae lies posterior to and a little below each spiracle. There are two isolated pairs situated on the hypopleural swellings; and on the dorsum, between the spiracles, there is a row of three pairs. On the succeeding segments the arrangement of setae is similar (fig. 5, e). There appear to be no special dermal structures.

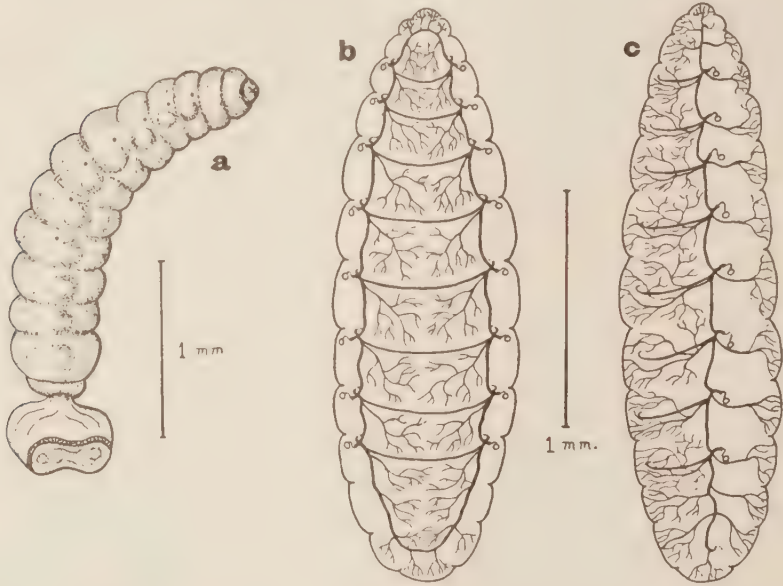


Fig. 3. *Apanteles sesamiae*, Cam., fully grown larva: a, lateral view, showing hypopleural swellings and caudal vesicle; b, dorsal; and c, lateral view of respiratory system.

The head can be partly withdrawn into the prothorax, and the cuticle is thickened and more rigid than that on the body. With the exception of a portion of the maxillary areas, the cuticle of the head bears minute spiniform structures somewhat similar to those on the general integument but with longer bases than the latter. The facial rods are, in general, well developed (fig. 4). The mandibles possess strong bases, rectangular when viewed from behind, basally deeply emarginate when viewed from the front and triangular in section. The apical portion is curved and tapers to a blunt point. The total length of a mandible, including the base, is 0.18 mm., the width across the condyles 0.063 mm. and near the first tooth 0.019 mm. There are ten strong, more or less rectangular teeth set closely together and with their apices markedly flattened. The apical points of the mandibles are simple and not bifurcate as in some species of *Apanteles* (fig. 5, a, b). The mandibles articulate laterally with the frontal struts, the latter being short, stout rods provided with the usual socket and groove. There is no indication of a frontal arch, and the struts end more or less abruptly just above the mandibles. Anteriorly they articulate with the mandibular struts which are well developed, 0.27 mm. long, 0.019 mm. wide posteriorly and 0.025 mm. wide near their junction with the maxillary struts. Further forward they taper to a blunt point, the portion anterior to the maxillary struts being curved and passing beneath the mandibles to form supports for the bases of the latter. The maxillary struts are short, 0.05 mm. long, 0.013 mm. wide

at their bases and tapering to a broad point apically. Basally they are fused to the mandibular struts, their apical points being free but articulating with the labial struts a little more than midway along the length of the latter as measured from the labial ring. The labial struts pass across the face from near the posterior extremities of the mandibular struts to the upper portion of the labial ring with which they articulate, forming the fulcrum on which it swings. They are stout rods, 0.20 mm. long, 0.019 mm. wide at the centre, 0.025 mm. wide at their posterior extremities, where a marked thickening occurs, and 0.038 mm. across their points of articulation with the labial ring. The latter is simple and slender, roughly hexagonal in shape, with the two basal angles rounded and somewhat indistinct, and is not markedly compressed in any one direction. The horizontal diameter of the ring is 0.188 mm. and the vertical diameter 0.175 mm. (inside measurements), while the rod itself is approximately 0.013 mm. thick.

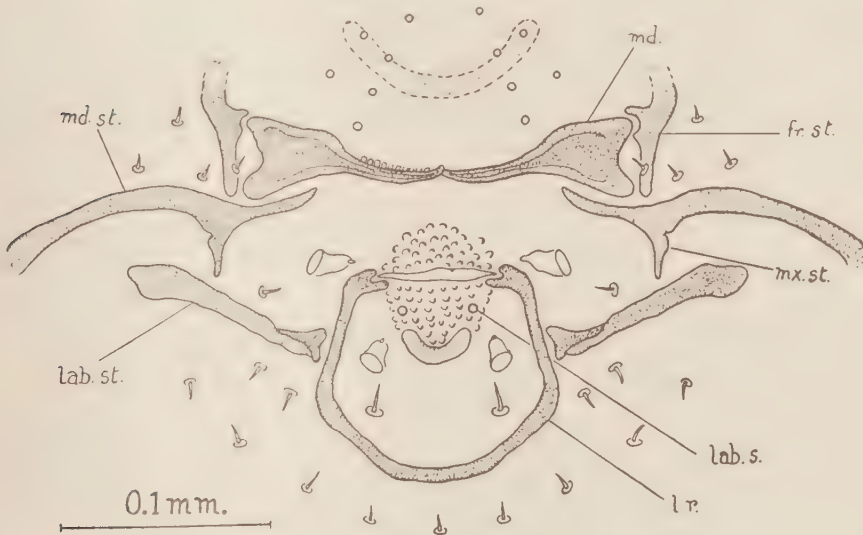


Fig. 4. *Apanteles sesamiae*, Cam., mouth-parts, facial rods and facial setae of fully-grown larva: *md.*, mandible; *md.st.*, mandibular strut; *mx.st.*, maxillary strut; *lab.st.*, labial strut; *lab.s.*, labial sensilla; *l.r.*, labial ring; *fr.st.*, frontal strut.

The labral area bears two groups of four fairly large setae, each group being situated in the angle formed laterally by the frontal and mandibular struts; and two groups of six very short setae set upon conspicuous bases, arranged one on each side of the centre line and each group comprising an inner line of four and an outer line of two setae respectively. A maxillary area on each side of the face is bounded by the anterior portions of the mandibular and labial struts together with the whole of the maxillary strut. Each of these areas bears a single large seta and a prominent tubercle, 0.038 mm. high, erected on a circular, sclerotic base with a diameter of 0.031 mm. The tubercle is surmounted apically by a single, small sensory papilla (fig. 5, c). The labial area, bounded by the labial ring, bears a pair of setae, somewhat longer than those on other parts of the face, and situated one near each of the lower lateral angles. In addition, there is a pair of tubercles similar in structure to those on the maxillary areas but slightly smaller, being 0.031 mm. high and with a basal diameter of 0.025 mm. It has been suggested by other writers that these tubercles represent the maxillary and labial palpi of the adult, and it seems most likely that

this homology is correct. Immediately below the mouth-opening, which is 0.119 mm. wide, is the spinneret. Situated one on each side of the spinneret, is a pair of small sensoria. On the area beneath the labial strut, on either side of the face, are two pairs of setae arranged in a roughly rectangular pattern, while beneath the labial ring is a curved row of five prominent setae. No sign of antennal organs was observed.

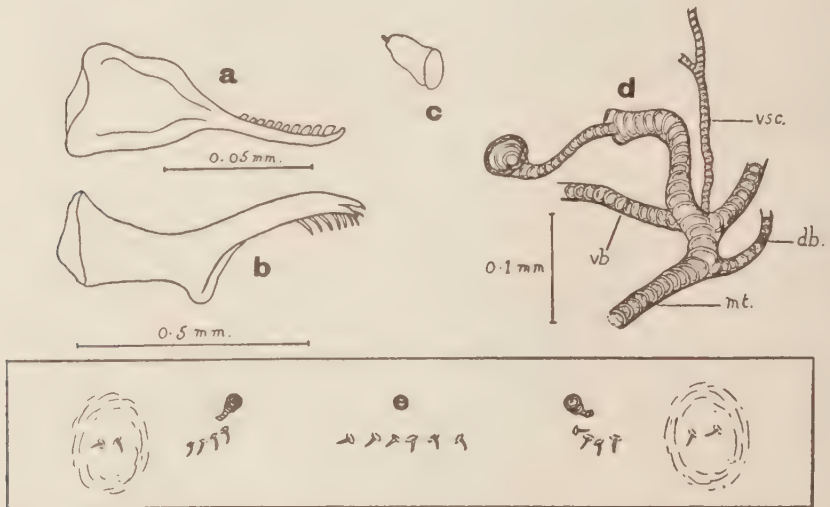


Fig. 5. *Apanteles sesamiae*, Cam., fully-grown larva: **a**, mandible; **b**, mandible of *A. diparopsidis*, Lyle; **c**, maxillary tubercle; **d**, spiracle and tracheal branches; *mt*, main trunk; *vb*, ventral branch; *db*, dorsal branch; *vsc*, visceral branch; **e**, setal map of 3rd post-cephalic segment.

The internal skeleton of the head comprises the anterior and posterior arms of the tentorium and the pharyngeal trough, the latter being an unpaired, lightly pigmented sclerite well within the head. The posterior arms of the tentorium arise at the basal extremities of the mandibular struts, to which they are fused. They then pass backwards, curve slightly upwards, and finally meet and fuse to form a single, stout and unpigmented rod which extends across the posterior portion of the head-capsule and runs beneath the pharynx. The anterior arms of the tentorium arise from slightly raised points a little beyond the centres of the posterior arms. They are poorly developed and are represented by tenuous, colourless structures which soon become threadlike towards their apices. They require careful dissection and their anterior points of attachment could not be discerned. The latter, however, must be well forward as the threads are fairly long.

The respiratory system (fig. 3, **b, c**) consists of two main lateral trunks connected with functional spiracles opening near the anterior margins of the metathorax and abdominal segments 1 to 7. The trunks are joined anteriorly in the prothorax and posteriorly in the 9th abdominal segment by commissures. A little behind the stigmatic trunk, in each case, the main tracheal trunk gives rise to a ventral branch which crosses the body and joins its fellow from the opposite side without branching. There are formed thus eight ventral commissures. A dorsal branch leaves the main trunk slightly in front of the stigmatic trunk and extends for some little distance without branching. It does not meet its opposite, however, but eventually branches extensively and ramifies throughout the dorsal viscera of the segment. Secondary branches are present in every segment, arising from the main trunk, passing inwards

and ramifying extensively. The head and anal segments are supplied by secondary branches leaving the extremities of the main trunks.

The present species agrees with other Braconid larvae in the possession of a curved, or sickle-shaped, mandible with a single row of strong and prominent teeth; in the shape and structure of the simple, slender labial ring; and in the absence of an accessory longitudinal tracheal commissure. Following Seurat (1899), the latter character has been used extensively to distinguish the larvae of the BRACONIDAE from those of the ICHNEUMONIDAE, but Salt (1931) has recently shown that this distinction breaks down in the case of the Pimpline, *Collyria calcitrator*, Grav., which, however, appears to be an unusual type in other ways. From the examination of a number of preparations of the mouth-parts and facial rods of Braconid and Ichneumonid larvae and a consideration of the literature available, the conclusion seems to be that, with our present knowledge, the only features by which they can be separated with any degree of reliability are the shape of the mandibles, the arrangement and appearance of the teeth and, perhaps, the structural characters of the labial ring.

As mentioned above, the mandible in some species of *Apanteles* has a divided apex which, incidentally, provides it with two large additional teeth. A similar condition has been observed by the writer in other genera of endoparasitic BRACONIDAE. While, in itself, this peculiarity has therefore no generic significance, it is undoubtedly a diagnostic character of value in interspecific determinations.

The degree of development of the frontal arch in the larvae of BRACONIDAE appears to be correlated with their feeding habits. Thus, in species of *Microbracon*, which are external feeders, as for example, *M. brevicornis*, the arch is strongly developed; in *Orgilus obscurator*, Nees, an internal parasite, Thorpe describes this structure as being weak and only faintly pigmented; while in the present species, in *Apanteles diparopsidis*, Lyle, and in other cases of internal feeders examined by the writer, it is entirely absent.

Biology and Bionomics.

The fully-grown larva of *A. sesamiae* invariably emerged from the 5th or 6th instar larvae of the host. It seems, therefore, that the adult parasite chooses for oviposition a host which is approximately in the middle of its larval life. Each host is capable of supporting to maturity a relatively large number of *Apanteles* larvae. The actual number varies considerably and in cases under observation anything from 12 to 120 fully developed larvae emerged from a single borer. Commonly from 60 to 100 cocoons are produced. The white cocoons are spun within the lumen of the stalk of the maize and are loosely held together with strands of fine silk, the whole mass often surrounding the now sluggish host but attached to the walls of the burrow. At 26°C. and 80 per cent. relative humidity the pupal period occupies from 5 to 7 days. A fairly high humidity seems to be essential at this time, and this condition is found to obtain in the normal environment. Removal to dry conditions is detrimental to the pupa and more often than not results in death before emergence takes place.

Both males and females are produced from each mass of cocoons and mating takes place very shortly after emergence. As a general rule, males were found to emerge first and to wait near the cocoons until the females emerged. Under laboratory conditions it was found that direct sunlight was not essential at this time, but that a well lighted position gave optimum activity. Without food the adults are short-lived and die within 24 hours. When food was supplied in the form of raisins or sugar solution, longevity was increased, but to no appreciable extent. Both males and females fed readily at the cut ends of the maize stalks in the breeding-jars and with the plant juice thus made available they could be kept alive for three or four

days. Where food was given feeding took place prior to mating. For oviposition the female enters the opening of the larval burrows of the host and attacks the latter within the restricted area provided by the lumen formed in feeding. In the laboratory it was found that parasitism could not be obtained successfully unless similar conditions were provided. For rearing, therefore, sections of maize stalks were used in which artificial burrows and entrance-holes were made with a cork-borer of suitable size. The attractiveness of these stalks for the parasite was apparently further enhanced after some feeding of the borer had taken place and a little frass had accumulated. This seems to indicate that the location of the host is largely a matter of olfactory stimulus. The period from oviposition to the emergence of the fully-grown parasite larva varies from 14 days in the warmest part of the summer to 21 days during the cooler weather of late summer and early autumn. The mean daily temperatures for the period of the year during which observations were made are shown in the chart in fig. 6.

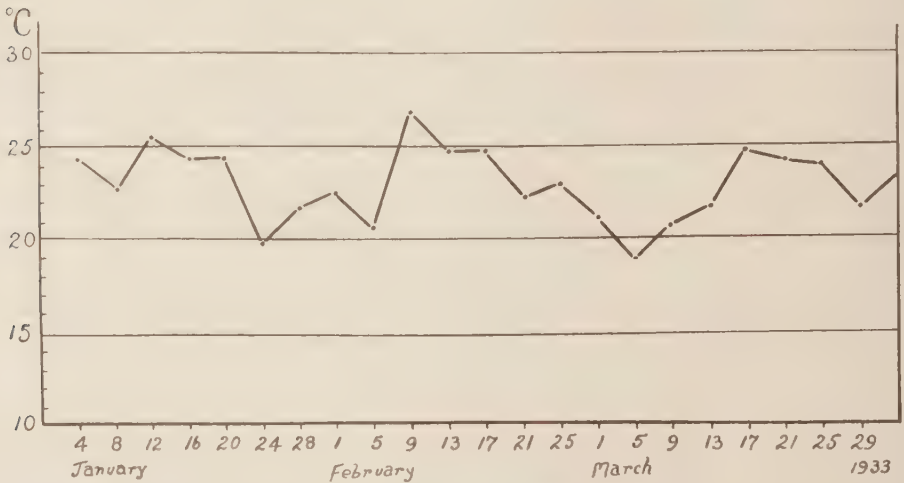


Fig. 6. *Apanteles sesamiae*, Cam.: mean daily screen temperatures for the period in which observations were made. The chart is based on 4-day means of the thermograph records read at two-hourly intervals.

There is nothing in the external appearance of a parasitised stalk-borer larva to distinguish it from a normal, healthy individual during the time when the parasites are feeding internally. The only noticeable departures from the normal are a more voracious feeding on the part of the host and a definite prolongation of the later stadia. After emergence of the parasites, however, the larva is very easily recognised. It becomes flaccid, moves very sluggishly if at all, sometimes wanders aimlessly about, takes little or no food and finally dies before pupation occurs. The appearance of dark, irregular areas on the integument of the body are characteristic at this stage. In no case under observation did a parasitised larva even attempt to pupate. The value of the parasite lies, therefore, not so much in an immediate amelioration of the amount of damage done to a maize crop by the host, as in the reduction of future infestations by the destruction of potential females.

The Extent of Parasitism in the Field.

In order to form an estimate of the efficacy of the parasite under natural conditions and to ascertain the most profitable time of the year at which to make large-scale collections of the host larvae, fields of maize were sampled at intervals during the

period when general observations showed that the stalk-borer was most numerous. The method of examination adopted gave a 22 per cent. sample of the plant population in each field taken, the sample plants being spread throughout the area. The larvae and pupae of *B. fusca* which were present in these plants were collected and retained for the determination of parasitism.

The first appreciable infestation of borer was noticed towards the end of February. At this time 4.7 per cent. of the plants were found to be infested and there was a parasitism by *A. sesamiae* to the extent of 2.9 per cent. of the larvae collected. At the beginning of March, a week later, the infestation of borer was much the same (4.14 per cent. of the plants examined), but the larval parasitism by *Apanteles* had increased to 22.8 per cent. At the end of March, when the last rain-grown maize crops were ripening off, the percentage of infested plants had fallen to 0.5 per cent. and the larval parasitism had further increased to 59.1 per cent. The latter high figure is undoubtedly due, in part, to the relatively low host population. From the foregoing, however, it is clear that *Apanteles sesamiae* is able to increase rapidly in the field and is a very efficient parasite of *B. fusca*. A large measure of its success can be ascribed to the scarcity of hyperparasites. One species only was found, attacking the pupa of *Apanteles*, but this was present in only 2 per cent. of the cocoon-masses observed and it appeared somewhat late in the season.

Cold Storage Experiments.

In most cases where the transportation of parasites from one locality, or country, to another occupies a considerable time interval, the most convenient method of shipment is usually that of sending the pupal or prepupal stage of the parasite in some form of cold storage. By the courtesy of the Union-Castle Mail Steamship Company, it was found that two distinct ranges of temperatures were available on the mail steamers leaving South Africa for England. The meat and fish rooms are maintained at 18° to 22° F. and the vegetable rooms at 38° to 44° F., the relative humidity in both cases being in the neighbourhood of 90 per cent. The voyage from Cape Town to Southampton is accomplished in 17 days, while the total travelling period from Barberton to England is approximately three weeks. A quantity of freshly pupated material was subjected to these temperatures for a corresponding length of time. The trials were conducted in a multiple temperature incubator and the lower range was obtained by the use of cryohydrate solutions. In the 38°–44° F. temperature range slow development of the pupae took place, as evidenced in the darkening of the contents of the cocoons. On being removed from storage and gradually brought into higher temperatures the pupae matured in 24 hours, but the resulting adults were so enfeebled that they were unable to cut their way out of the cocoon. In the lower range, development was retarded to a much greater extent but was still insufficiently so for the purpose in view and, as in the previous case, no emergence was obtained after removal. Further trials, in which pupae in all stages of development as well as prepupae were used, showed conclusively that it was impracticable to send consignments under the conditions available.

Following a suggestion of Mr. F. S. Parsons, attention was then directed to the possibility of shipping parasitised larvae. As the minimum period spent within the host was found to be 14 days, it proved possible to send small consignments of borer larvae, contained in short sections of maize stalks, to England by Imperial Airways. This obviated the necessity of cold storage en route and trial lots showed that the material carried well, the parasite cocoons being formed after arrival when they could be forwarded to the final destination. With the improved schedule of the air liners the method becomes even more valuable. The disadvantages, which led to a search for an alternative route, are the high cost of transport and the postal weight limit. Further tests were therefore carried out on the effect of low temperatures on the host and its contained parasites, again using the temperature ranges available

on the mail steamers. In this case it was necessary to extend the period of exposure to cover the voyage from Southampton to Canada. The lower range was immediately ruled out by the fact that a few days' exposure resulted in the death of the host larvae. The higher range, on the other hand, was found to have the desired effect and the development of the parasites was retarded sufficiently to allow of the material arriving in Canada before pupation occurred. Shipments of parasitised larvae, in which the latter were contained in cut lengths of maize stalks, sent to Canada via England under the conditions mentioned have confirmed the laboratory findings, and the material has provided a nucleus for a breeding stock of the parasite which, at the time of writing, gives promise of usefulness against the European Corn Borer. A comparison of the effect of low temperatures on parasite and host seems to indicate that the threshold of development of the former is lower than that of the latter—an encouraging sign when its probable success in a colder climate is being considered. From laboratory observations and from the fact that the parasite occurs under the high veld conditions of South Africa where hard frosts are common in June, July and August, there is ample reason for believing that the pupal stage of *Apanteles sesamiae* is able to withstand a severe winter.

Summary.

1. *Apanteles sesamiae*, Cam., is the only parasite of *Busseola fusca*, Fuller, which is of importance in the Eastern Transvaal.
2. The adult is described, and the morphology of the last stage larva of the parasite is discussed in detail.
3. The biology and bionomics of the species are dealt with, and the effect of parasitism on the host is described.
4. The extent of natural parasitism and the rapidity of increase in the field shows that *A. sesamiae* is an effective parasite of the Maize Stalk-borer in South Africa.
5. The results of cold storage experiments are given and the methods of shipping parasite material are described. It was found impracticable to ship cocoons, but successful consignments of parasitised borer larvae were sent to Canada.

Acknowledgments.

The author desires to express his indebtedness to Mr. F. S. Parsons, Officer in charge of the Insect Pest Control Section of the Empire Cotton Growing Corporation, for much encouragement and advice given during the course of these studies and for permission to publish this paper; to Mr. A. B. Baird of the Dominion Parasite Laboratory, Belleville, Ontario, for regular reports on the condition and progress of the material after arrival; and to the Cape Town Agency of the Union-Castle Mail Steamship Company, Ltd., for unfailing courtesy in supplying information relative to the storage facilities on the Company's steamers and for their co-operation in the handling of the various consignments. The arrangements in transit at Southampton were carried out by the Farnham House Laboratory under the direction of Dr. W. R. Thompson.

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FURTHER NOTES ON THE FOOD-PLANTS OF NIGERIAN INSECTS. III.

By F. D. GOLDING, M.A., F.R.E.S. *ONE*

In 1927 and 1931 the writer published two papers on the food-plants of some Nigerian insects; the present paper contains additional data obtained since 1931. The writer wishes to acknowledge his indebtedness to the Imperial Institute of Entomology and the specialists of the Department of Entomology in the British Museum for identifying the insects mentioned and to Messrs J. West and O. J. Voelcker for supplying him with many of the Lepidopterous larvae.

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
LEPIDOPTERA.				
PAPILIONIDAE				
<i>Papilio nireus</i> , L. ...	<i>Citrus aurantium</i> ...	Leaves ...	Oct. ...	Ibadan
<i>P. demodocus</i> , Esp. ...	<i>C. decumana</i> ...	" ...	Dec. ...	"
DANAIDAE				
<i>Danaïa chrysippus</i> , L.	<i>Calotropis procera</i> ...	"	March	Kalkala (Bornu)
NYMPHALIDAE				
<i>Euphaedra ceres</i> , F. ...	<i>Deinbollia pinnata</i> ...	"	Jan. ...	Ibadan
LYCAENIDAE				
<i>Virachola antalus</i> , Hopff.	<i>Vigna catjang</i> , ... <i>Phaseolus lunatus</i> ...	Green pods "	Dec. Jan.	" "
<i>Euchrysops malathana</i> , Bdv.	<i>Vigna catjang</i> ...	"	Dec. ...	"
ARCTIIDAE				
<i>Utetheisa pulchella</i> , L.	<i>Trichodesma africana</i>	Leaves ...	Feb. ...	Kalkala
NOCTUIDAE				
<i>Prodenia litura</i> , F. ...	<i>Theobroma cacao</i> ...	" ...	Dec. ...	Agege
<i>Busseola fusca</i> , Hmps.	<i>Sorghum vulgare</i> ...	Stem ...	Oct. ...	Ibadan
<i>Laphygma frugiperda</i> , S. & A.	<i>Zea mays</i> ...	Leaves ...	" ...	"
<i>Spodoptera mauritia</i> , Bdv.	" ...	" ...	" ...	"
<i>Phytometra acuta</i> , Walk.	" ...	" ...	" ...	"
LYMANTRIIDAE				
<i>Dasychira georgiana</i> , Fawc.	<i>Phaseolus lunatus</i> ...	" ...	Jan. ...	"
<i>D. mediofasciata</i> , Hering	<i>Alchornea cordifolia</i> ...	" ...	Aug. ...	"
<i>D. carpenteri</i> , B. Bkr.	<i>Butyrospermum parkii</i>	" ...	Oct. ...	"
<i>D. proleprota</i> , Hmps....	" "	" ...	" ...	"
SPHINGIDAE				
<i>Deilephila nerii</i> , L. ...	<i>Alstonia congensis</i> ...	" ...	Jan. ...	"
<i>Hippotion celerio</i> , L. ...	<i>Talinum triangulare</i> ...	" ...	Oct. ...	"
<i>Polyptychus poliades</i> , Jord.	<i>Cola acuminata</i> ...	" ...	Nov. ...	"

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
LEPIDOPTERA—continued.				
LASIOCAMPIDAE <i>Trabala charon</i> , Druce	<i>Combretum micranthum</i>	Leaves ...	Aug. ...	Ibadan
LIMACODIDAE <i>Thoesa pepon</i> , Karsch	<i>Coffea</i> sp. ...	" ...	" ...	"
DREPANIDAE <i>Metadrepana glauca</i> , Hmps.	" ...	" ...	Jan. ...	"
PYRALIDAE <i>Maruca testulalis</i> , Hb. <i>Etiella zinckenella</i> , Treit.	<i>Vigna catjang</i> ... <i>Phaseolus lunatus</i> ...	Green pods Ripe beans	Dec., Jan. Jan., Feb. March	" "
LYONETHIDAE <i>Plemyristis oenochares</i> , Meyr.	" "	"	"	"
EUCOSMIDAE <i>Argyroproctus leucotreta</i> , Meyr. <i>Laspeyresia ptychora</i> , Meyr.	" ... <i>Citrus nobilis</i> ... <i>Phaseolus lunatus</i> ...	" Fruit ... Ripe beans	Feb. ... Sept. ... Dec. ...	" Ilorin Ibadan
RHYNCHOTA				
PENTATOMIDAE <i>Agonoscelis versicolor</i> , F. <i>Callidea natalensis</i> , St.	<i>Leucas martinicensis</i> ... <i>Trichodesma africana</i> ...	Fruit ... Fruit ...	Dec., Jan. Feb. ...	Kalkala, adults only " "
<i>Nezara viridula</i> , L. ...	<i>Phaseolus lunatus</i> ... <i>Crotalaria anagyroides</i> <i>Mucuna aterrima</i> ...	Green pods " "	Dec. ... Jan. ... " ...	Ibadan, adults and nymphs " " Ibadan, nymphs only
<i>Aspongopus viduatus</i> , F.	<i>Lagenaria vulgaris</i> ...	Shoots ...	" ...	Kalkala, adults and nymphs
<i>Atelocera raptoria</i> , Germ.	<i>Theobroma cacao</i> ... <i>Casuarina equisetifolia</i>	" ... "	Mar. ... Oct. ...	Umuahia, adults and nymphs Ibadan, adults and nymphs
<i>Antestia lineaticollis</i> , St.	<i>Coffea</i> sp. ...	Fruit ...	" ...	" "
COREIDAE <i>Anoplocnemis curvipes</i> , F. <i>Hypselopus gigas</i> , Burm.	<i>Citrus aurantium</i> ... <i>Acacia farnesiana</i> ...	Shoots ... Pods ...	Dec. ... April ...	" " Ibadan, adults only
LYGAEIDAE <i>Lygaeus pandurus</i> , Scop. <i>L. longulus</i> , Dall. ...	<i>Calotropis procera</i> ... " "	Seeds ... Buds ...	Mar., Apr. Feb. ...	Kalkala, adults only " "
CAPSIDAE <i>Helopeltis bergrothi</i> , Reut. <i>H. sanguineus</i> , Popp.	<i>Mangifera indica</i> ... <i>Psidium guava</i> ... " "	Shoots ... " "	Sept. ... Feb. ... " ...	Ibadan, adults only " " " "
CERCOPIDAE <i>Ptyelus grossus</i> , F. ...	<i>Ricinus communis</i> ...	Stems ...	Aug. ...	Ibadan, adults and nymphs

Name	Food-plants	Part attacked	Month of appearance	Locality and remarks
COLEOPTERA				
CETONIIDAE <i>Pachnoda interrupta</i> , F.	<i>Pennisetum typhoideum</i>	Seeds ...	Sept. ...	Potiskum, adults only
	<i>Abutilon</i> sp. ...	Fruit ...	Oct. ...	Kauwa (Bornu), adults only
COCCINELLIDAE <i>Epilachna chrysomelina</i> , F.	<i>Lagenaria vulgaris</i> ...	Leaves ...	Jan. ...	Kalkala, adults and larvae
GALERUCIDAE <i>Aulacophora foveicollis</i> , Luc.	" "	" "	Feb. ...	Kalkala, adults only
<i>Monolepta goldingi</i> , Bryant	<i>Lonchocarpus cyanescens</i>	" "	May, Aug.	Ibadan, adults only
<i>M. marginatus</i> , Jac.	" "	" "	Aug. ...	" "
EUMOLPIDAE <i>Eurydemus gossypii</i> , Bryant	<i>Gossypium</i> sp. ...	" "	May, Aug.	" "
<i>Patria gossypii</i> , Bryant	" "	" "	Aug. ...	" "
LAMIIDAE <i>Diasocera trifasciata</i> , F.	<i>Moringa pterygosperma</i>	Stem-girdler	Dec. ...	Potiskum, adults only
BOSTRYCHIDAE <i>Apate monachus</i> , F. ...	<i>Theobroma cacao</i> ...	Stem-borer	Feb. ...	Ibadan, adults only
SCOLYTIDAE <i>Stephanoderes hampei</i> , Ferr.	<i>Phaseolus lunatus</i> ...	Ripe beans	Dec. ...	" "
ANTHRIBIDAE <i>Araccerus fasciculatus</i> , de G.	" "	" "	Jan. ...	" "
CURCULIONIDAE <i>Paremydica insperata</i> , Fst.	<i>Cola acuminata</i> ...	Fruit ...	Nov. ...	Agege, adults and larvae
	" "	" "	Nov. to March	Ibadan, adults and larvae
DIPTERA				
TRYPETIDAE <i>Ceratitis cola</i> , Silv. ...	<i>Cola acuminata</i> ...	Fruit (testa only)	Oct. ...	Ibadan, larvae
<i>C. punctata</i> , Wied. ...	<i>Theobroma cacao</i> ...	Old pods	July ...	" "
<i>Dacus longistylus</i> , Wied.	<i>Calotropis procera</i> ...	Fruit ...	Feb. ...	Mongonu, "
	" "	" "	Mar. ...	Kalkala, "
ORTHOPTERA				
ACRIDIDAE <i>Poecilocerus hieroglyphicus</i> , Klug	<i>Calotropis procera</i> ...	Leaves ...	July ...	N'guru (Bornu), adults only
	" "	" "	Feb., Mar.	Kalkala, nymphs only
			Apr. to Jun.	Adults and nymphs
<i>Cyrtacanthacris aeruginosa unicolor</i> , Uv.	<i>Hibiscus esculentus</i> ...	" "	Sept. ...	Ibadan, nymph

ECOLOGICAL STUDIES OF THE GREENHOUSE THRIPS, *HELIOTHRIPS HAEMORRHOIDALIS*, IN PALESTINE.

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Introduction.

In Palestine, *Heliothrips haemorrhoidalis*, Bché., primarily attacks citrus trees. In the spring and early summer, the insects feed upon the leaves; towards the middle of June they migrate from the leaves to the fruit. Hidden places on the fruit, such as the point where two fruits touch, are, as a rule, more infested with this pest than the free areas. The feeding of the insect, in both its larval and its adult stages, brings about chlorotic areas on the fruit, which later on become smooth and silvery owing to the layer of cork which has formed on the surface.

The insect is most common in spots which are protected from strong light. Shady, thick, old groves are more infested with this pest than groves where the trees are young and well exposed to light. Only on one occasion, a few infested young trees of the age of 6-7 years were discovered. For the same reason, the interior parts of the trees are more infested than the periphery, and the insect is more common on the lower than on the upper side of the leaves. The abundance of the pest, however, is variable, and it was the aim of the work presented herewith to study the factors governing its outbreaks.

Technique of Breeding *Heliothrips haemorrhoidalis*.

The insects were reared on small fresh twigs of citrus. One end of the twig was placed in water and the other end, which served for feeding, was placed in a test-tube whose open end was closed with cotton wool (fig. 1, a). In this manner the twig remained fresh several days, and the insects fed upon it and laid eggs under its epidermis.

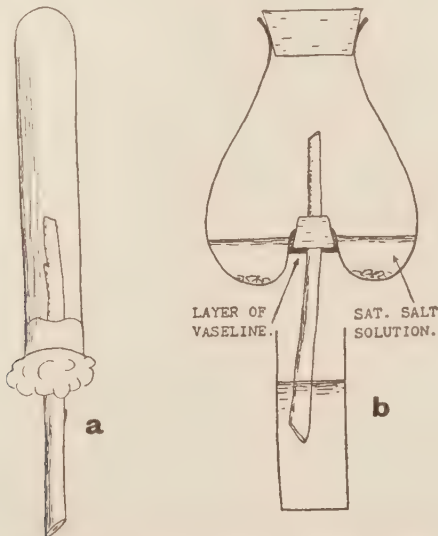


Fig. 1. a, twig in test tube for rearing thrips; b, twig in trap jar for rearing insects under controlled conditions of humidity.

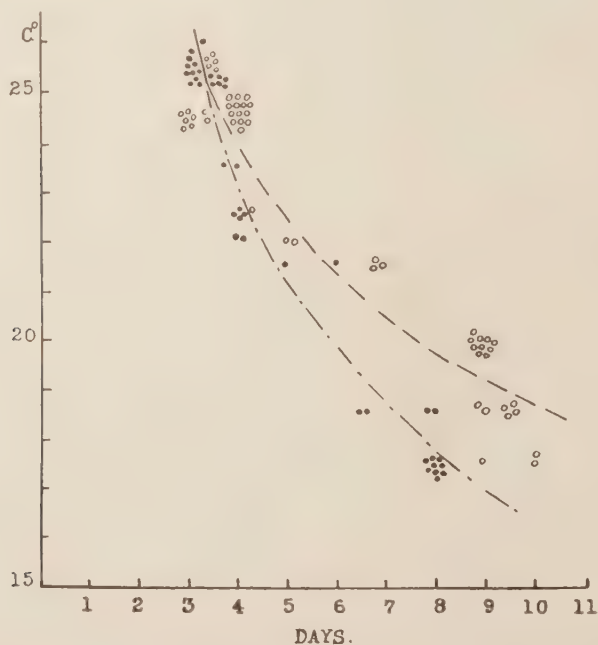
To study the development of the insect, young larvae were placed on the twigs immediately after hatching, and were under close observation until they reached the adult stage. In order to obtain an exact egg-laying record, individual thrips were given fresh food every two or three days and the eggs which had been laid during this period were counted on each twig after the females were removed from it. For the study of the development of the eggs and their mortality, individuals were put on young seedlings grown in pots and covered with a lamp chimney. The plant was also changed every four or five days; eggs were counted, the incubation period watched and the number of hatchings recorded. In this manner it was possible to record also the length of the incubation period, percentage of mortality of eggs, length of life of the individuals, and other phases in the biology of the insect.

To rear the thrips in controlled humidity, the twig was placed in trap jars (fig. 1, b) containing a concentrated solution of salts yielding various relative humidities, and a daily record of the temperature of the room was kept.

Effects of Climatic Factors on Development.

Effects of Relative Humidity.

Casual observations showed a small retardation in the rate of the development of the egg at drier atmospheric humidities, but the differences were quite small and negligible. To rear the eggs under conditions in which the humidity was artificially controlled proved to be impossible, because the eggs are inserted in the plant tissue, and the living plant, when placed in a closed vessel in which the relative humidity is to be controlled, upsets the desired conditions. This was the case also with the study of effects of relative humidity upon the larva.



In order to test the effects of atmospheric humidity upon pupae, newly moulted individuals were placed in small tubes closed at both ends with loose cotton wool. These tubes, in turn, were suspended in larger test-tubes quite close to concentrated salt solutions within the tubes. The salt solutions yielding various relative humidities were as follows: CaCl_2 for 30 per cent.; $\text{Ca}(\text{NO}_3)_2$ for 55 per cent.; NaCl for 75 per cent.; $(\text{NH}_4)_2\text{SO}_4$ for 81 per cent.; $\text{K}_2\text{Cr}_2\text{O}_7$ for 87 per cent.; KNO_3 , $\text{Pb}(\text{NO}_3)_2$, H_2O for 96 per cent.

It was found that a relative humidity of at least 75 per cent. was necessary for the pupa to complete its development. At a temperature of 25°C . there is hardly any difference in the rate of development of the insect whether it is at the relative humidity of 75 per cent. or 87 per cent. (fig. 2), but differences are more noticeable at the lower temperature of $18^\circ\text{--}19^\circ\text{C}$. In the latter case, the pupa completes its development within 8 days at a relative humidity of 87 per cent., and within 9.5 days at a relative humidity of 75 per cent., which makes a difference of about 15 per cent. of the total development time. This is explained by the fact that at a higher temperature the development is completed before the loss of water reaches the limit where its shortage could be disadvantageous to the growth of the insect.

Effects of Temperature.

The effects of the temperature on the rate of development of the various stages of the insect are given in a condensed form in Table I.

TABLE I.

Temperature	Development period in days				Combined total
	Egg	Larva	Pupa	Pre-oviposition period	
29	15	10.3	3	5	33.3
28	14.5	9.3	3	4	30.8
27	14	10.6	3	5	32.6
26	14.7	10	3.5	5.5	33.7
25	16	10	4	6	36
23	19	12	5	6	42
21	22.3	15.5	6	10	53.8
19	25	19	7	12	63
16	35	28.5	12	17	92.5
15	44	30	14	19	107

These records were obtained from several breedings made in the laboratory for a period of two years. It is to be noted that the quickest development of each of the stages takes place at a temperature of $26\text{--}28^\circ\text{C}$. The Blunck-Bodenheimer*† formula

* BLUNCK, H. 1923. Die Entwicklung des *Dytiscus marginalis* vom Ei bis zur Imago. 2. Teil. Z. wiss. Zool. **121**, pp. 171-391.

† BODENHEIMER, F. S. 1926. Über die Voraussage der Generationen-Zahl von Insecten. Z. angew. Ent. **12**, pp. 91-122. 14 415

agrees with the actual data only within certain limits, *i.e.*, within the temperature of 17–26°C. Within these limits the threshold for the larval development was found to be 13.2 and the thermal constant 117.

A curve which agrees with the actual data all through was found to be that of the following parabola :— $(Y-T)^2 = K(X-D)$. Y is the optimal temperature of development, *i.e.*, the middle degree of the optimal range of temperature ; X is the respective average development period, *i.e.*, the average development time from the data of the optimal range of temperature ; T is any other given temperature and D its respective development time. K is a constant which may be obtained when both T and D are given—thus $\frac{(Y-T)^2}{(X-D)} = K$.

A more extended discussion on this formula is given elsewhere.

Effects of Temperature upon Reproduction.

The effects of relative humidity upon reproduction are of little value because when the individual is well nourished the water taken in with the food presumably counterbalances the effects of the dryness in the air.

The major factor which influences the rate of reproduction is temperature. Under favourable conditions two eggs may be laid by one individual in a day, but at a temperature of 13–15°C. only five eggs were laid in a month, and the frequency of egg-laying increased as the temperature rose, as indicated in the accompanying graph (fig. 3).

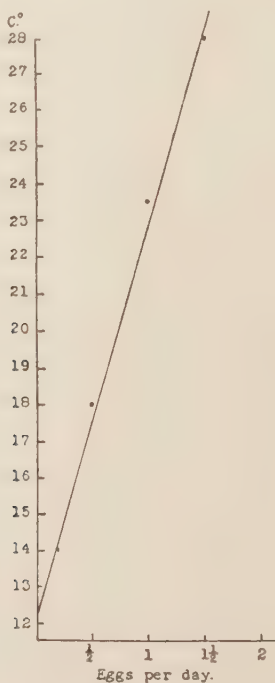


Fig. 3. Effects of temperature upon the rate of reproduction of *H. haemorrhoidalis*.

The total egg production of an individual also depends upon the changes of temperature, as shown in the following table.

TABLE II.

Prevailing temperature during the life-time of the individual	Number of individuals	Total number of eggs	Individual average
15.5-20°C.	63	1,594	25
20-25	28	1,330	47.5
25.5-28	49	2,235	46.6
28.5-29*	34	1,257	37

*Exposed daily to temperature of 30-35°C. for 3 hours.

The maximum production by one individual was about 62 eggs; on the average, 47 were laid by one individual under the most favourable conditions (21-28°C.).

Combined Effects of Relative Humidity and Temperature upon Mortality.

The effects of atmospheric humidity upon an insect depend upon the amount of water which is left in its body as the result of evaporation. If an insect continues to take moisture with its food to replace that which has been evaporated, the effects of atmospheric dryness may thereby be reduced to a minimum. But if the insect is not in a position to make up the loss of water from the body, its entire well-being depends upon the conditions of the atmospheric humidity, unless it is protected in one way or another against the loss of water.

For this reason the eggs and pupae of *Heliothrips* are subject to these effects more than the larval and adult stages. Although inserted in the leaf tissue the egg is, through the wound in the epidermis, directly exposed to the atmosphere, and changes in the latter may affect it. The pupa also does not feed and is greatly affected by the changes of moisture in the air.

Effects on the Egg.

The effects of moisture upon the mortality of the eggs could not be studied in an exact way, but some observations may be presented herewith (Table III).

TABLE III.

Number of plants	Location	Average temp.	Maximum temp.	Relative humidity	Total eggs laid	Total eggs hatched	Percentage of hatching
9	Outside	29	35	70	478	250	52.5
25	In room	27.5	31	75	365	988	72.4
9	Cellar	25	25.5	85	413	350	84.6

The mortality of almost half of the eggs in the plants which were placed outside was due to high temperatures. For although the average temperature outside was about 29°C., the maximum was always above 32°C. and often above 35°C. In the room where the maximum temperature was only 30°C., the mortality of eggs was less, whereas in the cellar the mortality was quite low, and even then it probably was due, to some extent, to the proliferation of cork cells as discussed later on.

Effects on the Pupa.

The effects of relative humidity upon the pupa were studied more exactly by the method already described above.

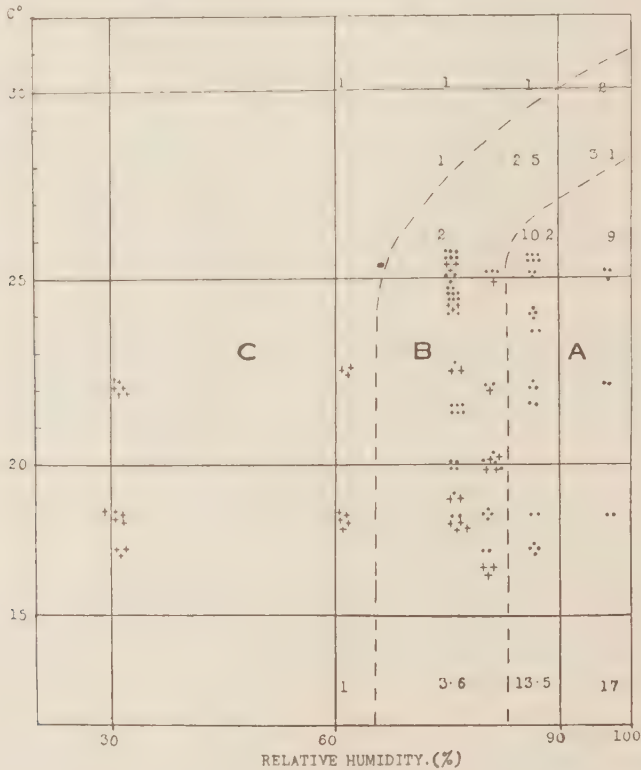


Fig. 4. Combined effects of temperature and relative humidity upon mortality of *H. haemorrhoidalis*. Black dots indicate pupae that have completed their development. Crosses indicate pupae that died before maturing. Numbers indicate the number of days adult insects survived without food.

The results of these breedings are given in a graph (fig. 4). A dot in these graphs indicates that the individual survived the conditions and moulted into an adult. A cross indicates that the individual died before or during the moult. It is noticeable that at a relative humidity of 60 per cent. and below the insects did not survive but died before moulting into an adult. At a relative humidity of 87 per cent. or above it, all individuals survived and moulted into adults. At a humidity of 75 and 81, two-thirds of the insects survived and one-third died before maturity. The percentage of survivals and deaths in this region varies with the temperature. One-quarter of the individuals died, and three-quarters survived, at temperatures above 21°C.; while at temperatures below 20°C. the ratio of deaths to survivals was 13:17. This may be explained by the fact that at higher temperatures the development of the pupa is so rapid that it is completed before the drying effects of the atmosphere have reached the detrimental point, whereas in a cooler atmosphere development is prolonged and the effects of dryness more pronounced.

Effects on the Adults.

Individuals reared in test-tubes throughout their lives lived longer than those reared on uncovered living plants. As noticed in Table IV, at lower temperatures they lived twice as long.

TABLE IV.
Length of Life in Days at Various Temperatures.

Average temperature	Individuals reared in test-tube	Individuals reared on plants
29-30	40	24
25-27	55	35
18-20	110	48

The difference in the length of life in this case is probably due to the atmospheric humidity, because both tubes and plants were kept in the same place, subject to the same changes of temperature, and the food on the living plant was presumably not inferior to that in the twigs. But while the atmospheric humidity in the test-tube was quite high (certainly above 85 per cent.), the humidity round the plants was 60-70 per cent. For this same reason, the individuals reared out of doors died quicker than those reared indoors.

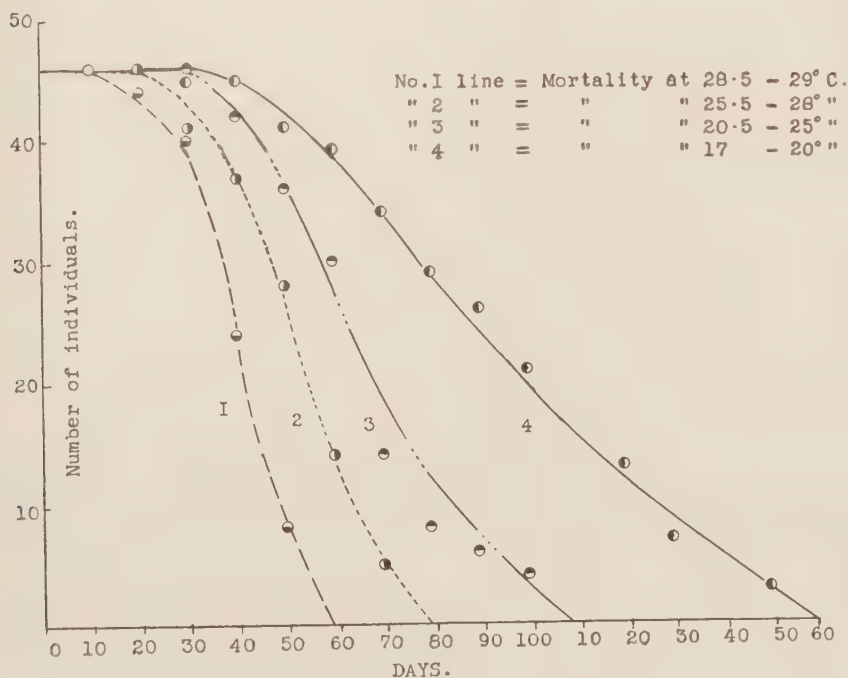


Fig. 5. Mortality of *H. haemorrhoidalis* at various degrees of temperature.

The effects of relative humidity upon the adult thrips are more noticeable when the insects are allowed to starve. Experiments were carried out wherein individuals were left to starve under different conditions of humidity. The procedure was the same as described in the case of the pupae, and the results obtained are given in a graph (fig. 4), every number being the average of 2-3 dozen individuals.

It is shown that under optimal conditions of temperature and humidity an adult *Heliethrips haemorrhoidalis* can survive from 10 to 15 days without food. Therefore, if an insect survives but one or two days, we may conclude that the premature deaths resulted from the unfavourable conditions of humidity or temperature. From the graph (fig. 4) it is evident that the safe region for the well-being of the individual is at a relative humidity above 85 per cent. and a temperature below 29°C. In this zone, which is marked A in the graph, adult individuals could survive over 9 days without food, and under these conditions 100 per cent. of the pupae developed into adults. The zone B in the graph is that in which the adults survived only 2-4 days without food, and about one-third of the pupae died before moulting. The third zone, C is the one in which adults survived starvation but one day or less, and no pupa developed into an adult.

The individual variability in the length of life at four different temperatures is given in fig. 5. Every line connects the number of deaths at a given temperature in intervals of ten days.

Temperature-Activity Scale of *H. haemorrhoidalis*.

As a result of the experiments on the effects of temperature on the reaction of the insect and observations throughout the breeding of insects, the following scale may be constructed :—

Temperature

in degrees C.

46	Immediate death.
41-45	Heat rigour ; insects fell off glass tubing.
34-40	Very feverish ; running dizzily looking for shelter.
29-33.5	Sluggish activity ; development and reproduction retarded.
26-28	Optimal temperature for development and reproduction.
16-25	Activity and development at a slow rate.
15	Activity ceases ; reproduction and development at a minimum rate.
11-12	Reproduction ceases.
6	Beginning of cold rigour ; very slight movement of antennae.
3-5	Cold rigour ; insects recovered after 30 minutes in such temperature.

Effects of Plant Tissue upon the Egg.

When the epidermis of the leaf is punctured and a foreign body inserted beneath it, the cells in the sponge tissue begin to produce a cork layer which surrounds the egg and separates it from the leaf tissue (fig. 6, a). This reaction seems to be of benefit to the egg, which is thereby protected from excessive moisture in the leaf and also furnished with a protective cover. This cover, however, is not sufficient to render it resistant to certain external stimuli and to the curling of the leaf due to wilting.

An injury to the egg by the leaf tissue may be caused by excessive proliferation of the cork-cells. Under conditions of high temperature and moisture in the air, or when the leaf is young and still in its growing stage, the proliferation of these cells, as a result of injury, may be so great that the egg is crushed inside the egg cavity, or if this growth is very proliferous it may burst the epidermis and push the egg out of the

leaf. Such reactions were quite common on some of the experimental plants and resulted in small cork warts (fig. 6, *b*). It should be mentioned here that the *Heliothrips*, as a rule, does not oviposit in fresh young leaves.

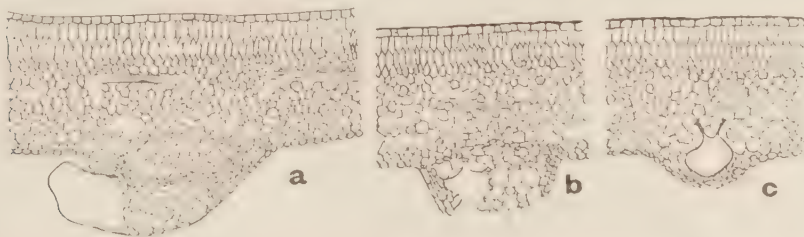


Fig. 6. *a*, egg of *H. haemorrhoidalis* laid in the leaf under the epidermis; *b*, cross section of cork wart showing cork cells and broken cavity where egg was laid; *c*, cross section of an egg which has become shrunken.

In order to give a better idea as to when such reactions take place, and to what extent they harm the eggs, the following descriptive notes may be useful.

TABLE V.

Plant no.	Condition of plant	Place during incubation period	No. eggs laid	No. hatched	Percentage hatched
16c	Suffered thirst; leaves withered, then recovered	Outside in shade; av. temp. 29, max. temp. 33-35	78	8	10.3
15c	Plant with soft, young leaves, covered with lamp chimney; many cork pimples on leaves	In the room; av. temp. 27, max. temp. 30	36	4	11
11c	Strong plant; many cork pimples	Cellar temp. 25; humidity 85 per cent.	29	12	43
14b	Plant suffered thirst	Outside in shade; av. temp. 29, max. temp. 33-35	20	10	50
18b	Strong plant, kept under water-tight chimney; cork pimples present	Room temp. 27 ...	56	33	68
16b	Strong plant, kept fresh always	Outside, in shade; av. temp. 29, max. 33-35	84	68	81
14	Fresh vigorous plant, uncovered	Room temp. 27 ...	45	42	93.3
22b	Ordinary plant, not too vigorous, old leaves	Cellar temp. 25; humidity 85 per cent.	90	89	98.8

Plants 14b, 16b and 16c were under the same conditions of temperature and humidity; because of thirst, however, 16c and 14b wilted, and the result is a lower percentage of hatching.

Plants 14b, 15c and 18b were also kept at the same temperature. As plant 15c had soft immature leaves and had been kept under a lamp chimney, the cell proliferation was strong and eggs were killed. The same was true of 18b, only not to so great an extent, because its leaves were more mature. When a vigorous plant like 11c was placed in the cellar, where the humidity was above 85 per cent., the same thing happened; otherwise the percentage of hatching was normal, as in plant 22b.

The question now is whether such is the case with eggs laid under natural conditions. The groves in Palestine are usually kept fresh and well supplied with water, so that the trees do not suffer from thirst. However, at times when there are hot, dry desert winds, the leaves, especially those grafted on sour orange stock, do curl, indicating an excessive amount of evaporation, and the eggs in such leaves are injured. Furthermore, there is no doubt that on a warm day following a good irrigation or a rain, the leaves, as a reaction against injury, are capable of proliferating cells enough to force out the foreign body in the leaf. Or it may be that the mortality of the eggs, under such conditions, is caused by turgor.

Effects of Climate on the Abundance of *H. haemorrhoidalis* in Palestine.

Upon a survey, it was found that there are at least five limiting conditions which control the abundance of the thrips in Palestine, as follows:—(1) The removal of the fruit from the grove; (2) the physiological state of the leaf (proliferation or cell turgor); (3) low relative humidity; (4) high temperature; (5) predators.

Of these factors the fifth is of least importance in reducing the number of thrips. The removal of the fruit is a more important factor, while the extent of the influence of the physiological state of the leaf cannot be established. Low relative humidity and high temperature are the most important factors in checking the population of the insect.

As mentioned above, the most favourable relative humidity is 85 per cent., for at lower humidities many eggs dry up. Furthermore, a humidity below 60 per cent. is detrimental to the pupal stage, the pupa dying before maturing. It is safe to conclude, therefore, that a hot desert wind, which lasts a few days, with a relative humidity of 30–60 per cent., is certainly detrimental to the pupae and probably also to the eggs. Such winds, and even drier ones, are quite common in Palestine during the spring and autumn.

A temperature above 33.5°C. is detrimental to the adult insect in general. It is true that the insect does not die immediately at this temperature, but its life is shortened and reproduction reduced. The pupa, however, is certainly harmed, especially when this temperature is coupled with a low relative humidity of below 70 per cent., which is a common occurrence.

Let us now see how these factors affect the species in Palestine. For this purpose, the changes in the population of the species during a certain period were studied, counts being made at intervals, as follows:—

In the neighbourhood of Hedera, counts were carried out at intervals of a month in four different groves known to be infested with thrips; 100 leaves were picked at random and the individuals counted, separate records being taken of larvae, pupae and adults (fig. 7, A).

Two years later, during 1933, other counts were made in three other groves in the neighbourhood of Jaffa—namely, one in Petach Tikvah, another in Mikveh Israel, and the third in Gan Warburg. In each grove 300 trees were picked at random, thoroughly examined, and the percentage of infested trees recorded. In addition, 300 leaves were picked in each grove and the percentage of infested leaves recorded as well as the number of thrips on each 100 leaves (fig. 7, B).

Analysis of Graph A (fig. 7).—It is to be noted that with the rise of temperature towards the end of February, many eggs that were probably laid in November, December and January, begin to hatch, the cold temperature during these months having prevented hatching before the warmer days of February set in. However, the number

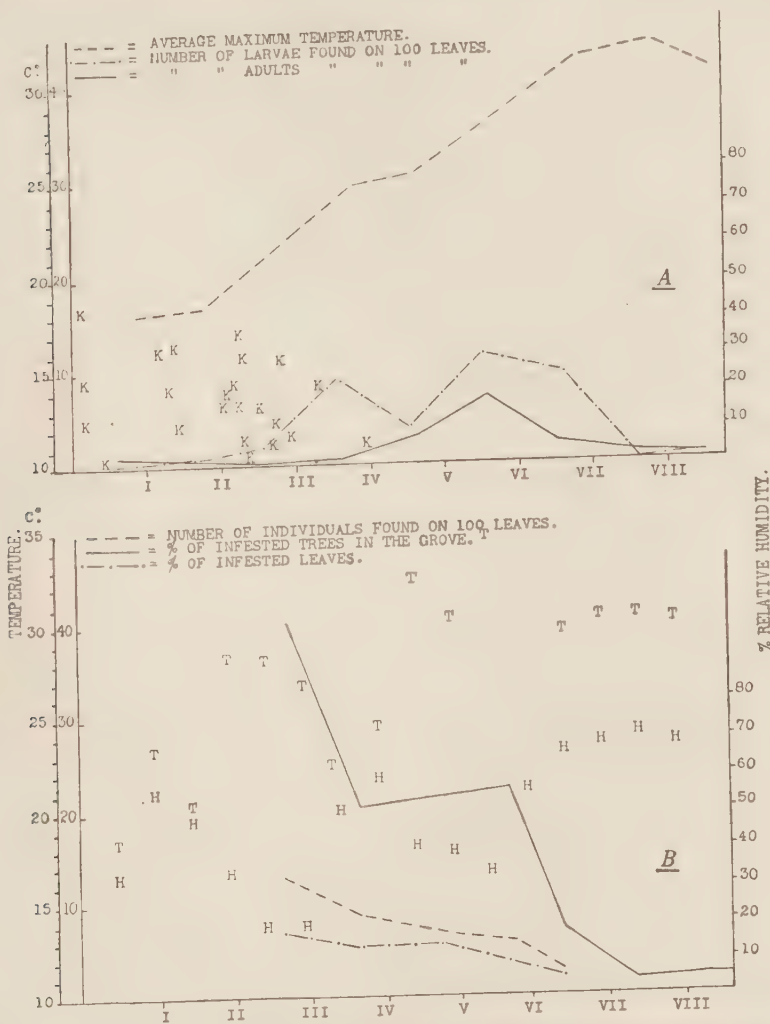


Fig. 7. *A*, influence of climate in Palestine on abundance of thrips both larvae and adults: K = "Hamisin" days (hot desert wind), the position of the letter indicating the minimum relative humidity of that day. *B*, influence of climate on extent of infestation: T = maximum temperature of each half-month; H = minimum relative humidity of each half-month.

of adults in the following month did not increase accordingly, but on the contrary even decreased during March and also in early April. This was due to the fact that the "Hamsin" days, with their low relative humidity, which could not affect the larvae, killed many of the pupae, so that few of them matured. The reduced number of adults during April caused a drop in the number of eggs and consequently in the

number of larvae during May. During the latter part of May and early June the temperature was very favourable for egg-laying and development, and conditions of humidity were also harmless, so that the number of both larvae and adults reached their peak during the month of June. Towards the end of this month, however, the temperature reached beyond the optimum limits, and we note a drop in the population, especially in the adults. The drop was still greater in the month of August. In these latter records, it should be remembered that the thrips in July began to migrate to the fruit and, therefore, the record is not altogether dependable.

Analysis of Graph B (fig. 7).—The rise in temperature towards the latter part of February and early March brought about an increase of infestation in March. Towards the end of April there followed a big drop in the infestation, which was primarily due to the picking of the fruit and removal of many individuals in all stages from the respective groves. A standstill in the number of thrips and infestation followed, and this condition lasted until the latter part of June. Prevention of increase was probably due to the warm days during this month. Then the temperature rose beyond the optimum limits (notice the high maximum during this half-month) and there followed a big drop in the infestation, which continued until the month of July. At this time the counts on the leaves were discontinued because the thrips begin to migrate to the fruit. However, the percentage of infested trees shows that the insect remained at a low level throughout the summer.

Summary.

1. The effects of humidity upon the rate of development of the egg, larva and pupa of *Heliothrips haemorrhoidalis*, Bché., is quite negligible.
 2. The rate of development and reproduction primarily depends upon the temperature.
 3. The larva and adult are more resistant to the ill effects of combined temperature and relative humidity than are the egg and pupa.
 4. Humidity of above 87 per cent. is the safe zone for the development of the pupa.
 5. A temperature-activity scale for *Heliothrips* is given.
 6. The plant tissue wherein the egg is laid may have a detrimental effect upon the egg under certain conditions.
 7. The effects of the particular climatic conditions of Palestine on the seasonal abundance of the insect are described.
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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st January and 31st March, 1935.

AGRICULTURAL OFFICER, QUETTA.—4 Culicidae, 2 Hippoboscidae, 5 *Lyperosia*, 19 other Diptera, 3 Coleoptera, and 6 Rhynchota; from Baluchistan.

Mr. E. BALLARD, Government Entomologist :—1 species of Aleurodidae and 90 Ticks; from Palestine.

Mr. A. H. BASTIN :—2 Coleoptera and 2 larvae; from Kashmir.

BERLIN ZOOLOGICAL MUSEUM :—598 Braconidae and 18 cocoons; from Germany.

Dr. H. BLÜNCK :—500 Parasitic Hymenoptera; from Germany.

Dr. F. S. BODENHEIMER :—275 Coleoptera and 21 Orthoptera; from Palestine.

Dr. BÖNING :—11 Parasitic Hymenoptera and 100 cocoons; from Germany.

Mr. P. BOVEY :—63 Parasitic Hymenoptera; from Switzerland.

Mr. H. J. BRÉDO :—42 Orthoptera; from the Belgian Congo.

Mr. A. E. BROOKES :—84 Coleoptera; from New Zealand.

Mr. E. H. BRYAN, Junr. :—11 Curculionidae; from Polynesia and Fiji.

Mr. L. L. BUCHANAN :—9 Curculionidae; from U.S. America and Porto Rico.

Mr. IVOR BULL :—3 species of Coccidae; from South India.

CHIEF ENTOMOLOGIST, PRETORIA :—91 Coleoptera, 4 Hymenoptera, 8 Rhynchota, and 5 Hemerobiidae; from South Africa.

CHIEF SANITARY OFFICER, BIRMINGHAM :—40 Coleoptera; from England.

Mr. S. F. CHIU :—41 Lepidoptera; from China.

Mr. J. T. CHU :—44 Parasitic Hymenoptera and 40 cocoons; from China.

Mr. A. F. CLARK :—1 Lepidopterous larva; from New Zealand.

Mr. G. H. CORBETT, Government Entomologist :—11 Tabanidae, 42 other Diptera, 58 Coleoptera, 336 Parasitic Hymenoptera, 79 other Hymenoptera, 107 Lepidoptera and 13 pupa cases, 20 Isoptera, 50 Rhynchota, 5 Psocidae, 3 Orthoptera, 5 Dermaptera, 4 Embiidae, and 7 Spiders; from Malaya.

Mr. G. S. COTTERELL, Government Entomologist :—51 Coleoptera, 12 Parasitic Hymenoptera, 6 Lepidoptera, and 21 Rhynchota; from the Gold Coast.

DEUTSCHES ENTOMOLOGISCHES INSTITUT :—62 Parasitic Hymenoptera and 10 cocoons; from various localities.

Mrs. DICKSON :—1 Coleopteron; from N.E. Arabia.

DIRECTOR OF PUBLIC WORKS, LAGOS :—380 Isoptera; from Nigeria.

Mr. A. P. DODD :—2 Curculionidae; from Queensland.

Dr. A. K. DRENOWSKI :—44 Orthoptera; from Bulgaria.

Mr. J. L. FROGGATT, Government Entomologist :—24 Diptera, 84 Coleoptera, 19 Hymenoptera, 17 Lepidoptera, 2 Thysanoptera, 1 species of Aleurodidae, 25 other Rhynchota, and 15 Orthoptera; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—63 Diptera and 30 pupa cases, 162 Curculionidae, and 61 Lepidoptera; from the United Provinces, India.

Dr. C. GAUTIER :—3 Braconidae; from France.

Mr. J. GHESQUIÈRE :—44 Curculionidae, 51 Parasitic Hymenoptera, and 2 Lepidopterous larvae; from the Belgian Congo.

Mr. F. D. GOLDING, Government Entomologist :—5 Coleoptera, 18 Hymenoptera, 2 Rhynchota, and 9 Orthoptera; from Nigeria.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—27 Coleoptera and 2 Thysanoptera; from South India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—150 Parasitic Hymenoptera, 125 Lepidoptera and 80 early stages, and 130 Isoptera; from the Punjab, India.

Mr. A. M. GWYNN :—8 Parasitic Hymenoptera and 1,004 Orthoptera; from Nigeria.

Mr. E. HARGREAVES, Government Entomologist :—39 Diptera and 6 pupa cases, 22 Coleoptera, 164 Parasitic Hymenoptera, 1,501 other Hymenoptera, 88 Lepidoptera, 270 Thysanoptera, 30 Rhynchota, 28 Orthoptera, 2 Trichoptera, and 1 species of Mite ; from Sierra Leone.

Mr. W. V. HARRIS, Assistant Entomologist :—7 Lepidoptera ; from Tanganyika Territory.

Mr. H. J. HOCKINGS :—50 Diptera, 2 Coleoptera and 10 larvae ; from Queensland.

Dr. W. HORN :—1 species of Mite ; from Tanganyika Territory.

IMPERIAL CHEMICAL INDUSTRIES :—500 Mites ; from England : and 70 Isoptera, from Malaya.

IMPERIAL ENTOMOLOGIST, PUSA :—100 Isoptera, 8 species of Aphidae, and 100 Mites ; from India.

INDIAN LAC RESEARCH ASSOCIATION :—45 specimens of Lac ; from Bihar, India.

INSTITUTE OF PLANT DISEASES, BUITENZORG :—17 Coleoptera, 29 Lepidoptera, 4 Thysanoptera, 5 Rhynchota, and 1,000 Mites ; from the Dutch East Indies.

Miss D. J. JACKSON :—1 Ichneumonid ; from Scotland.

Mr. H. B. JOHNSTON :—17 *Haematopota*, 27 other Diptera, 25 Hymenoptera, and 531 Orthoptera ; from Uganda.

Dr. W. A. LAMBORN, Medical Entomologist :—39 Tabanidae and 180 early stages, 31 Cecidomyiidae and 24 early stages, 24 other Diptera and 19 early stages, 2 Coleoptera, 80 Parasitic Hymenoptera, 20 other Hymenoptera, 5 Lepidoptera, and 5 pupa-cases, 2 species of Coccidae, and 2 Planipennia ; from Nyasaland.

Miss K. O. V. LIEU :—2 Lepidoptera and 10 early stages ; from China.

Sir H. LINDSAY :—3 Coleoptera, 4 Hymenoptera, and 122 Rhynchota ; from India.

Dr. LL. LLOYD :—76 Diptera, 67 Coleoptera, 10 Collembola, and 57 Spiders ; from England.

Mr. TSINGCHAO MA :—78 Curculionidae ; from China.

Prof. F. J. MEGGITT :—100 *Simulium*, 22 Coleoptera, 2 species of Aphidae, 2 other Rhynchota, 11 Orthoptera, and 2 Dermaptera ; from Burma.

Dr. B. DE MEILLON :—2 Tabanidae, 23 Psychodidae, 30 other Diptera, and 8 Curculionidae ; from Zululand.

Mr. H. M. MORRIS, Government Entomologist :—4 Culicidae, 4 Tabanidae, 3 Hippoboscidae, 102 other Diptera, 495 Coleoptera, 134 Parasitic Hymenoptera, 152 other Hymenoptera, 71 Lepidoptera, 20 Cimicidae, 113 other Rhynchota, 15 Orthoptera, and 5 Dermaptera ; from Cyprus.

Dr. H. K. MUNRO :—2 Diptera ; from South Africa.

MUSEUM NATIONAL D'HISTOIRE NATURELLE, PARIS :—23 Curculionidae ; from Africa.

Mr. F. B. NOTLEY :—50 Parasitic Hymenoptera ; from Kenya Colony : and 1 species of Coccidae ; from the Philippine Islands.

Messrs. H. T. PAGDEN and R. A. LEVER, Government Entomologists :—73 Diptera, 378 Coleoptera, 170 Parasitic Hymenoptera and 60 cocoons, 190 other Hymenoptera, 45 Lepidoptera, 250 Isoptera, 2 Thysanoptera, 1 species of Coccidae, 1 species of Aphidae, 78 other Rhynchota, 179 Orthoptera, 21 Dermaptera, 7 Planipennia, and 19 Odonata ; from the Solomon Islands.

Mr. R. W. PAINE :—22 Coleoptera, 6 Parasitic Hymenoptera, and 5 Lepidoptera ; from Fiji.

Messrs. O. B. PETER & SON :—5 Coleoptera ; from England.

Major H. ST. J. PHILBY :—11 Orthoptera ; from Arabia.

Dr. P. REGNIER :—61 Curculionidae, 2 Parasitic Hymenoptera, 106 Thysanoptera, and 58 Orthoptera ; from Morocco.

Dr. W. E. RIPPER :—225 Parasitic Hymenoptera ; from Austria.

Mr. A. H. RITCHIE, Government Entomologist :—301 Diptera, 81 Coleoptera and 8 larvae, 85 Parasitic Hymenoptera and 3 pupa-cases, 61 Lepidoptera, 2 Orthoptera, and 30 Mites ; from Tanganyika Territory.

Dr. W. ROEPKE :—25 Parasitic Hymenoptera and 25 cocoons ; from Argentina.

Mr. NIHAH SHEVKET :—6 Diptera, 9 Coleoptera, and 3 Hymenoptera ; from Turkey in Asia.

SELANGOR MUSEUM :—467 Coleoptera ; from Malaya and Borneo.

Mr. H. W. SIMMONDS, Government Entomologist :—5 Curculionidae, 2 Parasitic Hymenoptera, 3 Lepidoptera, 2 species of Coccidae, and 1 species of Aphidae ; from the Fiji Islands.

Mr. J. SUIRE :—7 Parasitic Hymenoptera ; from France.

Mr. O. H. SWEZEY :—3 Curculionidae ; from Hawaii.

Mr. C. B. SYMES, Medical Entomologist :—571 Tabanidae, 2 *Glossina*, 4 *Lyperosia*, 16 *Phlebotomus*, 34 other Diptera, 2 Coleoptera, 23 Hymenoptera and 3 early stages, 2 Isoptera, 31 Coccidae, 2 other Rhynchota, 2 Blattidae, 2 Ant-lion larvae, 3 Mallophaga, 4 Anoplura, 3 Ticks, 12 Mites, and 2 Crustacea ; from Kenya Colony.

Dr. O. THEODOR :—123 Orthoptera ; from Palestine.

UNITED STATES NATIONAL MUSEUM, WASHINGTON :—6 Braconidae ; from the United States of America.

Mr. G. C. VARLEY :—320 Parasitic Hymenoptera and 33 cocoons ; from England.

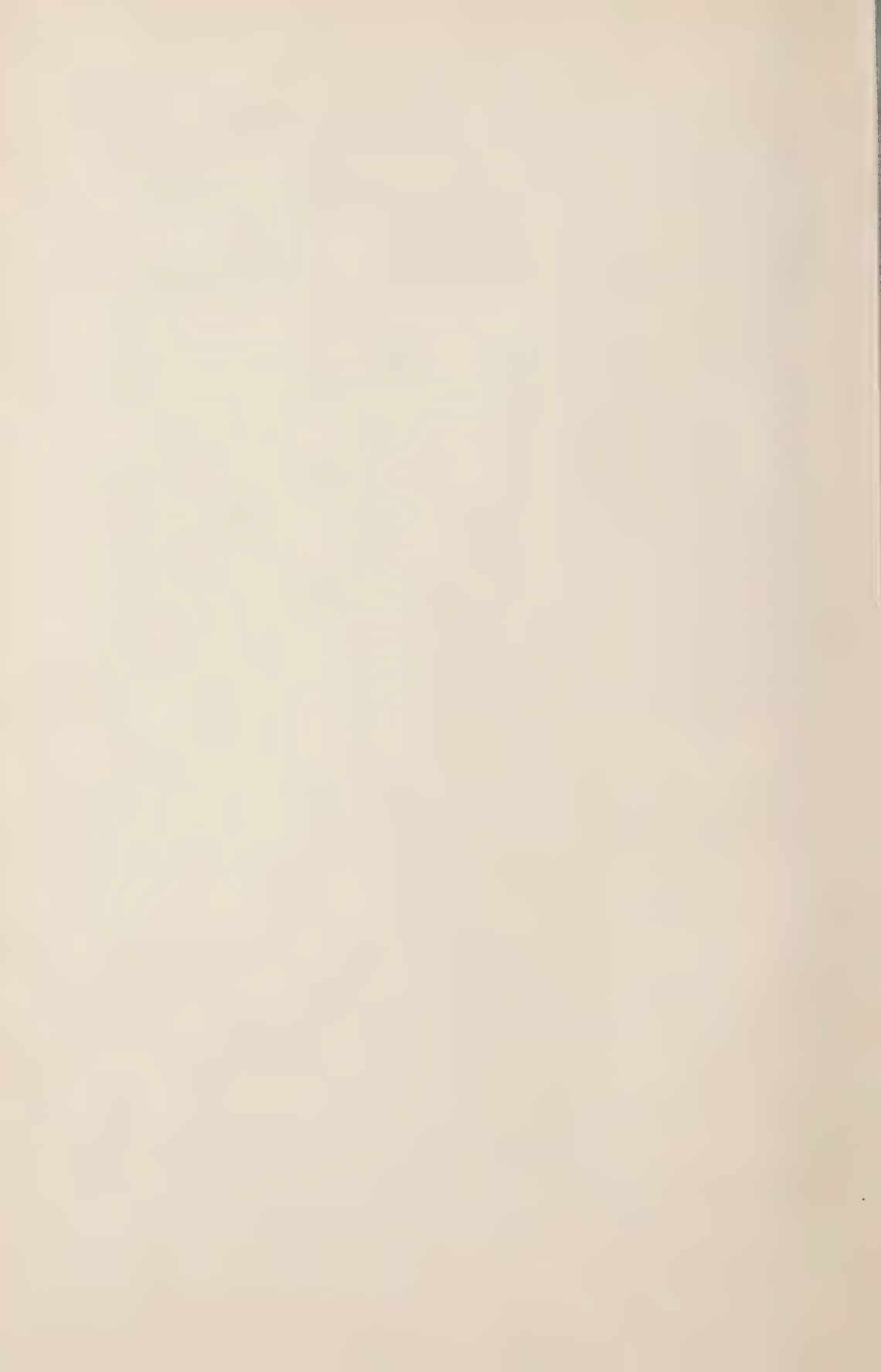
Mr. R. VEITCH, Chief Entomologist :—66 Coleoptera and 8 species of Coccidae ; from Queensland.

Mr. A. C. W. WAGNER :—405 Braconidae ; from Germany.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—72 Culicidae, 58 *Phlebotomus*, 14 Coleopterous larvae, 41 Parasitic Hymenoptera, 51 Formicidae, 2 Lepidoptera, and 44 Rhynchota ; from the Sudan.

Mr. F. N. WILLIAMS :—18 Lepidoptera ; from South America.

Mr. C. Y. WONG :—3 Diptera, 126 Coleoptera, 11 Hymenoptera, 42 Lepidoptera, 22 Rhynchota, 6 Psocidae, and 6 Orthoptera ; from China.



THE EFFECTS OF INTESTINAL POISONING ON THE BLOOD OF LOCUSTS (*LOCUSTA MIGRATORIA*).

By Professor M. PILAT.

Laboratory of Intestinal Insecticides in the Institute for Plant Protection, Leningrad, U.S.S.R., Russia.

(PLATES VII & VIII.)

The question of the effect of poisons on the blood of insects is a new one in entomo-toxicological literature. In a series of works by Metalnikov (1908, 1924, 1927) we have a study of the reaction of the blood of the larva of the Wax Moth (*Galleria mellonella*) in consequence of an injection into the body cavity of various substances and morbidiferous microbes. The paper by Mrs. Tareeva and Nenyukov (1931) describes, very briefly and in general features, the picture of the blood of *Calliptamus italicus* in the case of poisoning by means of sodium arsenate or sodium fluoride.

The object of the present work is to ascertain whether the action of the poison used affects the structure of the blood and whether the method of microscopic investigation, which has acquired great diagnostic importance in medicine, is applicable to the study of the action of intestinal poisons on insects.

My sincerest thanks are due to my friend, Prof. N. J. Kuznetsov, of the Academy of Sciences, Leningrad, for his constant assistance in my work.

Picture of normal Blood.

The insects investigated were larvae of the 5th instar and adult locusts immediately after the development of wings.

A drop of blood, taken by means of a capillary tube from a separated leg of the insect, was placed on a clean glass slip. Then, as usual, the blood was thinly spread on the slip and slightly dried, though some authors (Lazarenko, Muttkowski) do not unconditionally approve of the usual method of preparing this smear and suggest some modifications; but this method if properly applied gives excellent results, even for insects with most viscid haemolymph. Dried blood-smears were fixed by means of methyl alcohol (3-5 min.) and stained with a solution of Giemsa's mixture (1 drop to 1 cc. of distilled water) for 30-40 minutes. The staining substance was washed off with a strong jet of distilled water, and the smear was dried again in the air. The microscopic examination of the preparations was made with an oil-immersion lens, without inclusion in Canada balsam.

There is a considerable amount of literature on the morphology of the haemolymph of insects, but there are still several questions which have not yet been elucidated. Almost every author gives his own classification and nomenclature of haemocytes. Classifications are usually based on the following data: size and form of the haemocytes, correlation between the size of the nucleus and the cytoplasm, colour-reactions and physiological properties (particularly faculty of phagocytosis). Some authors, for instance, subdivide all haemocytes of globular form into small (up to 15 μ) and large (over 15 μ), while others, in spite of the differences in size, recognise only one type; some authors, again, establish special types for fusiform haemocytes and for those with granules in the cytoplasm. Thus opinions differ as to the number of types of haemocytes (from 2 to 6), and this number grows still greater when it is made to depend on such elements as myocytes in various

stages of disintegration and fat-body cells, neither of which, strictly speaking, are true haemocytes.

Without deciding beforehand the question of the number of types of haemocytes in the blood of the locust, I shall first give a description of the different forms of cells met with here, and then, if possible, endeavour to appreciate their significance in the general picture of the blood and their mutual relations.

Even after a cursory and superficial examination of preparations of blood the eye is caught by two forms of haemocytes, very different in their colour-reactions and approximately equal in number: one form with intensely coloured nuclei from violet to reddish-violet, and with a finely granulated, more or less sharply contoured cytoplasm; the other form with red nucleus and a pale-blue homogeneous cytoplasm without sharp contours, which often disappear entirely. The first form might be compared with the "chromophile leucocytes" in Muttkowski's classification, which show a strong affinity for aniline colours; the second form might be compared with the "amaebocytes," which can be but feebly stained with the same colours.

A detailed study of either form of haemocytes brings into view their utterly dissimilar morphological composition. The intensely coloured haemocytes with violet nuclei are, as to their exterior, formations of globular, or elongate shape, of very different dimensions, with variable relations of the nucleus to the cytoplasm. In the cytoplasm of some of them there is to be found a variable number of large granules of a red colour.

Globular haemocytes could be arranged, according to their size, in an uninterrupted series from small cells of 8-9 μ in diameter up to large ones reaching 31-32 μ (figs. 1-6).

The nuclei of these cells, globular or slightly oval, consist of small lumps of chromatin, differing in size and form, closely packed together, and masking the frame of the nucleus. It is impossible to discern the nucleolus among them. In the fine cells the nuclei take a dark violet colour; in the large cells the chromatin lumps lie less compactly, the nucleus has a lighter coloration, and red hues supplant the violet. The nucleus changes in colour from dark violet to reddish-violet, and finally to red-violet.

The relation of the nucleus to the cytoplasm also undergoes variation as the size of the cell increases. In the fine haemocytes (9-16 μ) the nucleus constitutes the main mass of the cell, the cytoplasm being reduced to a scarcely discernible rim around the nucleus (figs. 1, 2). In the larger haemocytes the size of the nucleus does not increase proportionally. Thus, for instance, in haemocytes of 21.5 μ and 31.5 μ in diameter the nuclei reach only a size of 14.9 μ . In large haemocytes the nuclei in most cases lie eccentrically (figs. 5, 6). The cytoplasm of all globular haemocytes shows a conspicuous basophilia, which is strong in the fine cells and somewhat weaker in the coarse ones. This cytoplasm has a finely granulated structure and sometimes is slightly vacuolized, especially in large haemocytes. It has proved impossible to discover here the circumnuclear region described by Muttkowski in reference to "chromophile leucocytes."

Haemocytes possess a power of amaeboid movement, which is proved by the presence of pseudopodia that are found in blood-smears (fig. 7).

In the above described series of globular haemocytes, which seems to me to be uninterrupted, some authors distinguish two or three types: *viz.* (1) small leucocytes or amaebocytes poor in protoplasm, (2) large leucocytes rich in protoplasm, with comparatively voluminous nuclei, and (3) large leucocytes with comparatively small nuclei (Cuénot, Metalnikov, Mrs. Tareeva and Nenyukov). Such a classification seems to me to be only conventional and obscures rather than elucidates the picture of the blood, because intermediate forms obliterate the boundaries between the principal types of haemocytes, so that counts of the different forms will lead to erroneous and contradictory results.

Fusiform haemocytes are a constant component part of the blood of the locust, although their numbers are less than those of the globular haemocytes (approximately $\frac{1}{4}$ of the latter). Owing to their peculiar and easily recognisable form some authors consider them as a special type of haemocytes (Hollande, Lazarenko, Mrs. Tareeva and Nenyukov). Their size varies from 20 to 43 μ (major axis) and from 6 to 11 μ (minor axis). The nuclei usually have an elongate form, are very compact, and in staining acquire an intense dark violet colour. The cytoplasm is basophile and acquires in staining a blue colour, which is more intense in smaller cells and lighter in larger ones; it has a finely granulated and sometimes reticular structure (figs. 8-10).

Lazarenko describes a special kind of haemocytes found in small amounts (1-2 per cent.) in the blood of *Oryctes nasicornis*, L. They are granular, eosinophile, oval cells (10-12 μ) with a protoplasm which is indifferent to acid and basic stains, with a very characteristic oxyphile granular structure.

In the blood of the locust also may be found in small numbers cells containing large red granules in the protoplasm. But they have not that constant form which Lazarenko attributes to his eosinophiles. Such coarsely granulated cells are to be found among the globular as well as among the fusiform haemocytes. Their protoplasm is always slightly basophile, and large red granules stand out in relief on its surface which is stained a pale-blue (figs. 11, 12). I see no reason why these cells should be considered as an independent group. In all probability, that is only a certain physiological state, a transient moment, in the life of the cell.

As mentioned above, in addition to the intensely coloured haemocytes in the blood of the locust there are to be found cells which take a comparatively weak coloration, with a red nucleus and pale cytoplasm. They have various sizes (from 19 to 30 μ and upwards), without sharp outlines and without constant form. Their nucleus is oval or globular, situated centrally in the cell, and always separated from the surrounding cytoplasm by a clear interstice. It is impossible to distinguish any definite structure in their nucleus, which seems to be perfectly homogeneous, slightly vacuolized, and may be stained a red colour by Giemsa's method. The cytoplasm shows slight basophilia, can be stained a pale-blue or bluish colour, and is homogeneous and more or less vacuolized (figs. 13, 14).

In one series of the haemocytes here described the protoplasm gradually discolors, loses its definite outlines, envelops the nucleus like a light shadow and, finally, wholly vanishes as if dissolving in the plasma of the blood. The nucleus remains naked without any trace of protoplasm, but still preserving its shape and coloration, and is easily discernible among the surrounding normal haemocytes (fig. 15).

In other cells it is the nucleus that begins to change, undergoing chromatolysis. The substance of the nucleus liquefies, as it were, and gradually overflows the whole cytoplasm, the pale-blue colour of the latter disappearing under the red of the former (fig. 16). Finally the cell becomes a red lump of indefinite form, undergoing vacuolization, especially on the periphery, and as a result assumes a complicated and curious shape (figs. 17, 18).

On account of what has been stated above, I am of opinion that pale-coloured cells with a red nucleus represent a senescent, degenerate form of haemocytes. The young and mature forms are represented by cells which in staining acquire an intense coloration and contain violet nuclei.

Thus, the normal picture of the blood of the locust presents different stages in the development of the haemocytes, beginning with youngest forms (cells of 8-9 μ) and ending with decaying and perishing forms represented by cells with red nuclei.

Besides the haemocytes, in the strict sense of the term, there are to be found in the haemolymph of insects formations which do not appertain to the formed elements of the blood proper, although such formations are sometimes described along with

them. Such are muscle-fibres in various stages of disintegration, so-called myocytes, sarcocytes and sarcolytes, as well as cells of the fat-body. These formations are also to be found in the blood of the locust.

The muscle-cells have the form of elongated fibres, up to $100\ \mu$ in length, with an oblong oval nucleus, or sometimes they are irregularly rounded formations with an angular pycnotic nucleus. In their protoplasm occur remains of myofibrillae, with still discernible transverse striation; in other cases they disappear altogether, and their nature can be deduced only by their characteristic nuclei (fig. 19).

The cells of the fat-body are large (up to $30\ \mu$ and upwards), of irregularly globular or oval form, and sharply contoured. Their protoplasm in staining takes a light blue colour and is compactly filled with red granules, which often mask the fundamental colour of the protoplasm itself (fig. 20). Sometimes these cells undergo disintegration; their borders become torn and irregular in outline, the sharp contours disappearing (fig. 21). The number of fat-cells in preparations is very inconstant. They may be entirely lacking in the first drop of blood taken and appear in great amounts in the following samples.

Picture of the Blood after Poisoning.

Poisoning was effected with sodium arsenite and sodium silico-fluoride in weak solutions (0.1 and 0.2 per cent.). Doses of poison absorbed by insects varied from 0.013 to 0.37 mgr. Blood was taken at different times, from 15 minutes to 56 hours, after poisoning, according to the energy of the poison and the behaviour of the insect. Blood-smears were fixed and stained by the same method used for normal blood.

The influence of the poison on the blood of insects is far from being discoverable in all cases, any more than it is in the intestinal epithelium. Even in the presence of unmistakable signs of poisoning and when the poisoned insect dies, the picture of the blood in most cases does not present any appreciable deviations from its normal condition.

I have not succeeded in discovering in haemocytes the changes which, according to Metalnikov's description, take place as a result of the injection of certain substances or microbes into the body cavity of the larvae of the Wax Moth (*Galleria mellonella*). It is certain that after an injection into the body cavity of insects there takes place a rapid physical and chemical change of the haemolymph which directly influences the blood cells, whereas in the case of poisoning through the intestinal tube such direct influence of the poisonous substance upon the haemolymph is absent.

The above-described forms of haemocytes of the normal blood of the locust are continually found in the blood of poisoned insects. Here are also to be seen globular cells with violet nuclei, haemocytes with granules in the cytoplasm, fusiform cells, pale cells with red nuclei, and red nuclei without any cytoplasm (figs. 22-33, 40-57).

Quantitative correlations between these forms of haemocytes do not present any characteristic features specifically relating to the blood of poisoned insects. In some cases pale cells with red nuclei and naked nuclei without cytoplasm may predominate, that is, degenerating forms; in other cases, on the contrary, intensely stained young forms may predominate.

When under the influence of the poisonous substance, the haemolymph undergoes more or less visible changes, which appear in two forms. In some cases it is disintegration and destruction of the haemocytes that take place, as described by Mrs. Tareeva and Nenyukov with regard to the blood of *Calliptamus italicus* poisoned by means of sodium arsenate.

Simultaneously with such disintegration, or independently of it, there are to be found, in other cases, among the haemocytes very minute cells and a greater or less number of mitoses. In the normal blood of the locust the smallest forms of

haemocytes, as has been stated above, are not less than $8-9\ \mu$ in diameter. Here they do not exceed $4-5\ \mu$. Their nuclei are still more compact and dark-coloured; the thin layer of cytoplasm round the nucleus is hardly discernible (figs. 34, 58).

The presence of very minute, *i.e.*, younger cells, as well as that of nuclei which are energetically dividing, must be considered as evidence of a regenerative process in the blood of the insect poisoned. Lazarenko, investigating the process of regeneration of the formed elements of the blood of the larva of *Oryctes nasicornis* after artificial bleeding, ascertained that during the first subsequent days there appear minute cellular forms from 2 to $2.5\ \mu$ in diameter. According to Lazarenko's statements, these forms in process of time pass through a complicated cycle of development and originate three groups of haemocytes: globular, fusiform, and granular eosinophiles; that is why Lazarenko called these cells "Urzellen" (primitive cells).

With the exception of some difference in size, which is easy to understand, the minute haemocytes of poisoned locusts are in all respects identical with Lazarenko's "Urzellen," and may be also considered as regenerative forms. But as that is only an attempt on the part of the organism at regeneration as a means of counter-acting the poison, no further development of this process takes place, and it is not followed by a transformation of the minute forms into more mature ones.

As the seat of generation of these minute blood-cells in the larva of *Oryctes*, Lazarenko exclusively recognises the internal blood-making organs, and among them the paired organ situated on the oesophagus near the corpora allata, which has been studied by him in a series of sections. Lazarenko has never observed any division of free cells in the blood-fluid and denies its possibility, but in this respect my observations disagree with his.

In preparations of blood taken from larvae of locusts poisoned with sodium arsenite or sodium silico-fluoride, mitotic figures of nuclei are frequently met with (figs. 35-39, 59-61), but the number of mitoses varies much in different preparations. The same applies to the smallest forms of haemocytes, which occur in varying amounts, and are not present in every preparation of poisoned blood.

The power inherent in every organism of resisting the effects of introduced poisons is the factor that determines the energy of the regenerative process which arises in the blood. The morphological picture of this process—generation of minute forms of haemocytes and dividing nuclei—is a reflection of the process of the struggle of the organism against the poison, and not a result of a direct influence of the latter on the formed elements of the blood.

Very significant in this respect is a series of preparations of blood taken from adult locusts with the following note: "*Death from an unknown cause.*"* That unknown cause was obviously no other than bacteriosis, for in many preparations are to be found bacteria whose nature I have not tried to determine.

The picture of the blood of these preparations is very characteristic owing to there being plenty of dividing cells. In one field may be found as many as four mitoses. The process of division is undergone here by haemocytes of all forms—globular (small and large) and fusiform. All stages of mitosis are also represented,

* Such a note ought not to discredit a preparation beforehand by making it appear that there was some possibility of post mortem changes in the blood. It is very difficult to determine the exact moment of death. An insect is usually thought to be dead, if it is quite motionless and does not show any reactions in response to excitation, etc. But with insects poisoned by gaseous substances I frequently found opportunities to convince myself that this belief is inconsistent with the real state of things. An insect taken out of the poisoning chamber does not show any motion and reactions on excitation, but it gives blood for microscopic smears in like manner as do living insects, and one or two days afterwards all other insects of this experiment come to life again. It seems to me that an insect can be declared dead only in the case when it does not furnish blood for microscopic smears, or if the fluid taken from the insect, in the preparation made from it, presents a picture of complete disintegration and destruction of blood-elements.

from spiremes to diasters. Figs. 62-67 clearly reproduce the above-described picture of the blood.

Obviously, in this case, as well as in the case of poisoning, there was carried on against the morbid principle an energetic fight which resulted in an outbreak of regenerative processes in the haemolymph of the insect.

As a result of what has been stated above I have come to the conclusion that the picture of the blood of an insect affected by intestinal poisoning is a very complicated phenomenon. Until precise and uniform principles for the classification of the formed elements of the haemolymph of insects have been established, it will be quite impossible to give a numerical expression (haemogram) for the picture of the blood after poisoning. All such haemograms would now be utterly conventional and of small utility in the hands of other investigators.

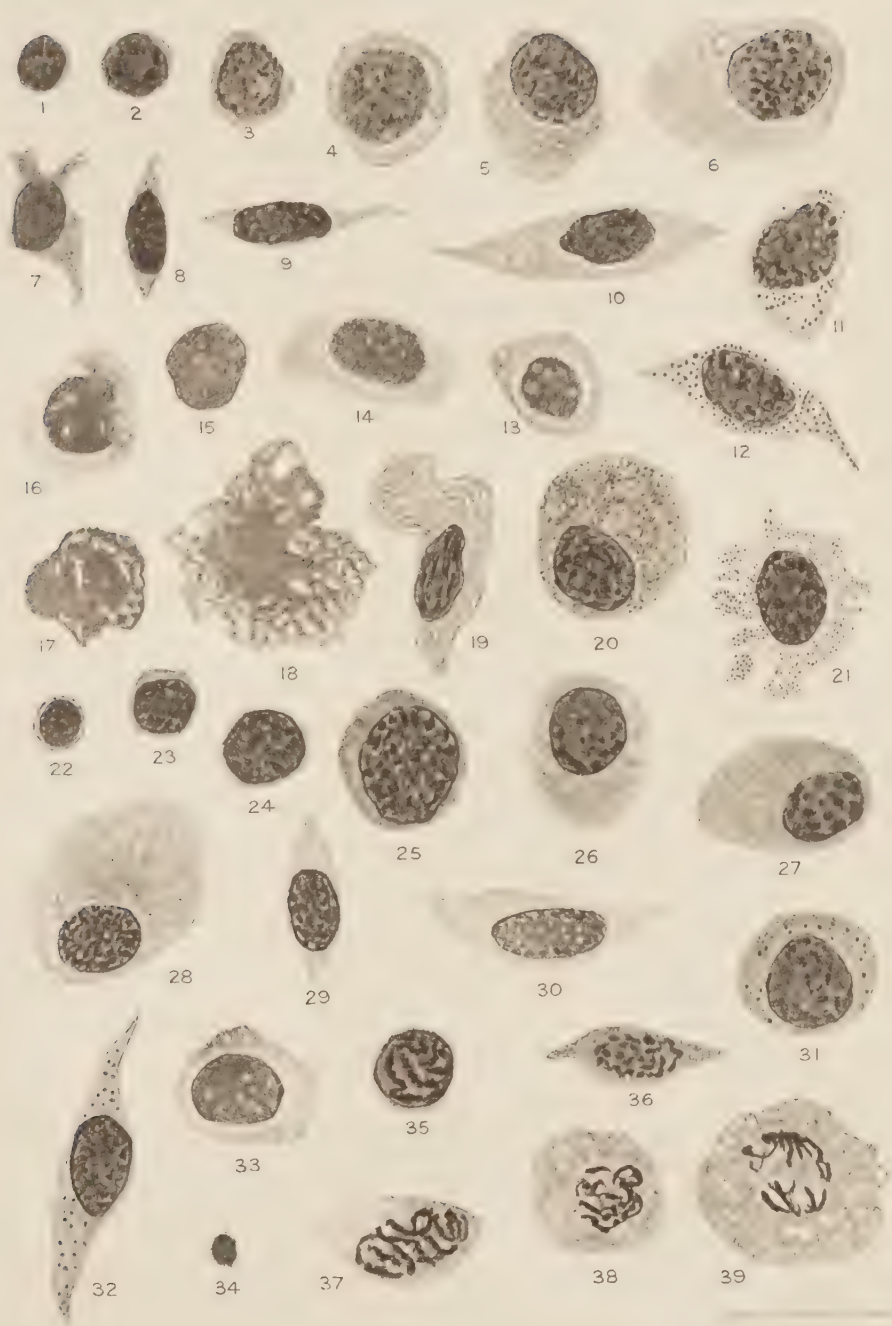
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EXPLANATION OF PLATE VII.*

- Figs. 1-21. Normal blood of locusts of the 5th instar.
- Figs. 1-6. Haemocytes of globular shape, with violet nuclei and blue cytoplasm, of gradually increasing size—8.5 μ (fig. 1), 11.6 μ (fig. 2), 14.9 μ (fig. 3), 18.2 μ (fig. 4), 21.5 μ (fig. 5), 31.5 μ (fig. 6).
- Fig. 7. Haemocyte with pseudopodia; nucleus violet; cytoplasm blue.
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- Figs. 11-12. Haemocytes with red granules in cytoplasm; nucleus violet; cytoplasm blue; sizes: 18.2 μ (fig. 11), 29.8-13.2 μ (fig. 12).
- Figs. 13-14. Haemocytes with red nuclei, pale-blue homogeneous cytoplasm and circumnuclear region; sizes: 19.9 μ (fig. 13), 24.7 μ (fig. 14).
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- Figs. 22-39. Represent the picture of the blood of locusts of the 5th instar, after poisoning by means of sodium arsenite.
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- Fig. 34. Haemocyte of most minute dimensions, 4.9 μ , with violet nucleus (regenerative form), 27½ hours after poisoning with 2 per cent. solution; dose 0.18 mgr.
- Figs. 35-39. Haemocytes with mitotic figures in various stages.
- Figs. 35-36. Compact spiremes, 49 hours after poisoning with 0.1 per cent. solution; dose 0.09 mgr.
- Figs. 37-38. Loose spiremes; fig. 37, 21 hours to 40 hours after poisoning (0.2 per cent. solution, dose 0.09 mgr.); fig. 38, 47 hours after poisoning (0.1 per cent. solution, dose 0.02 mgr.).
- Fig. 39. Diasters, 47 hours after poisoning (0.1 per cent. solution, dose 0.02 mgr.).

* The figures have been drawn with a Leitz drawing prism (Zeichenokular 2), on the level of the work-table. Reichert's microscope, Obj. 1/12, imm.



NORMAL AND POISONED BLOOD-CELLS
OF *LOCUSTA MIGRATORIA*, L.

EXPLANATION OF PLATE VIII.

- Figs. 40-61. Blood of locusts of 5th instar after poisoning with sodium silico-fluoride.
- Figs. 40-57. Haemocytes of normal blood ; globular, of gradually increasing size, with violet nuclei and blue cytoplasm (figs. 40-48) ; fusiform (figs. 49-51), with red granules in blue cytoplasm (figs. 52-54) ; with red nuclei, pale-blue homogeneous cytoplasm and circumnuclear region (figs. 55-56) ; red nucleus without cytoplasm (fig. 57).
- Fig. 58. Minute haemocyte, $4.9\ \mu$, with dark violet nucleus (regenerative form), 8 hours 10 minutes after poisoning (0.2 per cent. solution, dose 0.07 mgr.).
- Figs. 59-61. Haemocytes with mitotic figures in various stages.
- Fig. 59. Compact spireme 4 hours 15 minutes after poisoning (0.1 per cent. solution, dose 0.16 mgr.).
- Fig. 60. Loose spireme, changing into a monaster, 2 hours after poisoning (0.2 per cent. solution, dose 0.06 mgr.).
- Fig. 61. Monaster 4 hours 15 minutes after poisoning (0.1 per cent. solution, dose 0.16 mgr.).
- Figs. 62-73. Blood of adult locusts destroyed by an unknown cause.
- Figs. 62-67. Haemocytes of normal blood : globular, with violet nuclei and blue cytoplasm (figs. 62-64) ; with red nucleus, pale-blue homogeneous cytoplasm and circumnuclear region (fig. 65) ; fusiform, with violet nuclei and blue cytoplasm (figs. 66-67).
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- Figs. 69-73. Haemocytes with mitotic figures in various stages.
- Fig. 69. Loose spireme.
- Figs. 70-71. Monasters.
- Figs. 72-73. Diasters.
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NORMAL AND POISONED BLOOD-CELLS
OF *LOCUSTA MIGRATORIA*, L.



ECOLOGIE DU CRIQUET MAROCAIN EN IRAQ.

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(PLATES IX–XI.)

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1. Introduction.

Au mois de mars de l'année 1933 j'ai accepté l'invitation de Monsieur E. Guest, Officier inspecteur de l'Agriculture en Iraq et en même temps Botaniste, de visiter l'Iraq pour lui aider dans quelques travaux qu'il voulait poursuivre, et le 30 mars j'ai quitté Jérusalem, accompagné par Monsieur Guest et par Monsieur M. Zohary, mon assistant et collaborateur. Arrivant à Bagdad les premiers jours d'avril, j'ai été invité par Monsieur le Ministre des Economies et des Communications et par le Directeur Général de l'Agriculture de faire cette visite au compte du Gouvernement Iraquien et de m'intéresser pendant mon tour spécialement aux problèmes de la botanique appliquée et particulièrement au problème des sauterelles et du reboisement et de l'afforestation. J'ai accepté volontiers cette invitation. Il me fallait prolonger le séjour en Iraq de dix jours de plus qu'il a été projeté d'abord. Ces dix jours étaient presque entièrement consacrés à l'étude de la végétation des champs de ponte des sauterelles.

J'ai le plaisir de remercier ici toutes les personnes qui ont aidé de manières différentes à la réussite de ce voyage et tout d'abord Monsieur Rustam Beg Haidar, Ministre des Economies et Communications, Monsieur Anwar Beg Khayat, Directeur Général de l'Agriculture, M. J. F. Webster, Inspecteur Général de l'Agriculture, qui ont plané ma tournée en Iraq et m'ont introduit dans les problèmes de l'Agriculture Iraquienne. M. B. P. Uvarov, de l'Institut Impérial d'Entomologie à

Londres, qui a avancé et a défendu l'idée de la nécessité des investigations géobotaniques pour la lutte contre les sauterelles et à qui je dois mes premières connaissances du problème des sauterelles marocaines. Dr. J. Magnes, le Chancelier de l'Université Hébraïque de Jérusalem, qui a eu la bonté d'arranger le prolongement de mon séjour en Iraq. Puis Monsieur Muhammad Effendi ar-Rādhī, le Directeur du Service de la protection des plantes de l'Iraq, Monsieur A. Dutt, Entomologiste, Département de l'Agriculture, et d'autres membres du même service, qui m'ont prêté aimablement leur concours en ce qui concerne le problème des sauterelles. Enfin tous les autres fonctionnaires Iraquiens et Anglais en Iraq, qui m'ont livré à maintes reprises des informations utiles, et particulièrement Monsieur Khalil Eff. Feddo, Directeur de la Station Expérimentale de Rustam, Major W. C. F. Wilson, Inspecteur de l'Administration, Mosul, Captain C. H. Gowan, Inspecteur de l'Administration, Kirkuk.

Si ce voyage a donné, comme je l'espère, en un minimum de temps un maximum de résultats, j'ai le plaisir de souligner ici, que cela revient en grande partie à mes compagnons de voyage, à Monsieur Guest et à Monsieur Zohary, grâce aux parfaites connaissances du pays du premier et aux vastes connaissances floristiques du second.

Presqu'une année et demie se sont écoulées depuis que ce rapport a été présenté au gouvernement d'Iraq, mais par des causes imprévues sa publication a été ajournée. La partie qui traite de la végétation de champs de ponte des sauterelles marocaines apparaît maintenant dans le " Bulletin of Entomological Research."

J'ai relu cette partie de nouveau, j'y ai inséré quelques observations de B. P. Uvarov et j'ai fait quelques changements dans 2 ou 3 autres places d'après ses conseils. Pour ses observations et conseils, ainsi que pour l'intérêt qu'il a témoigné à la publication de cette partie de mon rapport je lui exprime encore une fois ma profonde reconnaissance.

2. Quelques faits généraux phytogéographiques et phytosociologiques de l'Iraq.

Notre voyage, tout court qu'il ait été pour un pays si vaste comme l'Iraq, nous permet d'y distinguer déjà cinq subdivisions principales au point de vue phytogéographique.

(a) *La partie septentrionale du Grand Plateau Arabique.*

La première subdivision est la partie septentrionale du grand plateau arabe (autant qu'il appartient à l'Iraq), dont nous avons touché la partie orientale sur une distance de 30 km. dans la direction S. de Az Zubair et dans une distance de 130 km. à peu près pendant notre traversée Basrah-Baghdad.

Au point de vue phytogéographique cette partie est la seule partie de l'Iraq nettement Saharo-Sindienne (Eig 1931) par la composition de sa flore. Du point de vue phytosociologique l'absence d'une couverture végétale dense et plus ou moins serrée, même au printemps, est très caractéristique, puisque mêmes les plantes annuelles sont éloignées l'une de l'autre à 7-10 cm. au moyen. La richesse comparative en espèces, comparée à la pauvreté de la continuation immédiate de cette partie (le " Désert Syrien ") est aussi un trait prominent. Puisque nous n'avons touché que le bord S.-E. de cette subdivision, qui n'est sûrement pas la plus caractéristique (l'altitude moyenne de la partie traversée est toujours restée au dessous de 100 m.), le tout nous est moins connu que les autres parties de l'Iraq. Sa végétation et son écologie sont bien particulières, et l'exploration géobotanique de cette partie de l'Iraq présente non seulement un intérêt purement scientifique, mais aussi économique.

C'est la partie de l'Iraq qui est complètement en dehors des invasions des sauterelles marocaines. Ce fait confirme ainsi notre suggestion que d'après son écologie, *Dociostaurus maroccanus* est en dehors des conditions saharo-sindiennes.

De l'autre côté de la grande plaine mésopotamienne, sur la même latitude, aux pieds des montagnes perses, il paraît que la même végétation, mais moins développée, caractérise les chaînons des collines et des petites montagnes.

(b) *La partie iraquienne du Grand Désert Syrien.*

La continuation directe de la première subdivision au nord est la partie iraquienne du grand Désert Syrien. Nous l'avons traversée deux fois ; les deux routes sont éloignées l'une de l'autre de 170 à 250 km. Nous avons reçu une idée générale assez nette de sa végétation et des notions principales de son écologie. Son aspect printanier est un steppe à herbe courte et généralement serrée, dont le composant principal est la *Poa bulbosa*. Le sol est couvert alors de 70-80% par la végétation qui présente un pâturage excellent. La durée saisonnière de cet aspect gai est bien courte. Vers la fin d'avril cette végétation éphémère est en général déjà complètement fanée. Sur de grandes surfaces pendant le reste de l'année la végétation a alors presque complètement disparu. Le nom de "Désert Syrien" ne convient bien que maintenant à cet aspect triste. Mais dans d'autres parties du "Désert Syrien" surtout éloignées de son centre, des associations de buissons nains se développent vers la fin du printemps ou même plus tôt (Pl. x, fig. 2). *Poa* avec ses satellites ne présente dans ces associations que l'aspect printanier, et les surfaces occupées par ces associations des buissons nains présentent trois aspects saisonniers : (1) l'aspect d'un steppe vert-gai à herbe courte et serrée (*Poa* et ses satellites) ; (2) l'aspect estival d'un steppe ouvert, gris ou grisâtre à buissons nains ; (3) vers la fin d'été, après que ces buissons ont aussi presque disparu, c'est un aspect d'un désert presque complet.

Il est bien naturel, que pour le ménage des bédouins la répartition de ces types de végétations, leur composition, la durée de leur vie, les causes de leur expansion ou restriction etc. présentent un énorme intérêt, et leur exploration méthodique doit entrer dans le cercle d'intérêt du Département de l'Agriculture de l'Iraq.

Dans sa partie méridionale le Désert Syrien (partie iraquienne) est tout à fait négatif pour le développement des sauterelles marocaines. Par contre, la partie septentrionale, vers le Djezireh, paraît être infestée en partie pendant des années des grandes invasions.

(c) *La grande plaine aluviale mésopotamienne.*

Cette plaine dans les parties visitées par nous n'atteint jamais l'altitude de 100 m. et a généralement moins de 50 m. Dans les parties arrosées (soit de nos temps ou aux anciens temps) la végétation halophytique (saline) se développe, surtout dans la partie méridionale de la plaine. Ce sont les halophytes "humides" (principalement les espèces de *Suaeda* et *Schaginia*) qui s'y développent (Pl. x, fig. 3). On peut dire en toute sûreté que cette végétation est une "fonction d'arrosage". Cette végétation se développe aussi en maintes localités d'épandages des fleuves. Sa composition et sa densité sont des indicateurs fidèles du grade de la salinité du sol, et l'étude de leur écologie et de leur genèse présente aussi un intérêt pratique.

Des grandes surfaces dans cette plaine sont couvertes par des associations pastorales à herbes annuelles. Leur distribution, leur composition, leur écologie et leur genèse présentent un intérêt économique. Il paraît que *Prosopis* et *Capparis* jouent un rôle important dans la composition de la végétation climatique d'une partie de cette plaine au moins. Mais puisque notre traversée dans cette plaine s'est faite presque exclusivement dans les parties soumises aux cultures modernes ou anciennes, nous avons pu étudier presque seulement des associations secondaires, rudérales, ségétales ou pastorales. Pour avoir une idée de la végétation naturelle et ainsi de l'écologie de cette plaine, l'exploration de ces parties en dehors des cultures anciennes ou modernes est nécessaire.

Dès maintenant nous devons mentionner un fait phytosociologique d'une grande portée pour nos considérations sur la question des sauterelles : l'association (ou la

série des associations) climatique des herbes hémicryptophytes touffues de *Poa*—*Carex* paraît faire défaut dans cette plaine, et ce sont les thérophytes (les annuelles) qui dominent son aspect printanier. Dans notre traversée de Bagdad—Arbil nous pûmes fixer le passage critique entre ces deux types de végétation printanière au nord de Deltawa, quelques 100 km. N. de Bagdad.

Cette partie d'Iraq est presque entièrement en dehors des champs de ponte permanentes des sauterelles marocaines, mais toute sa partie septentrionale est dans les limites des invasions presque régulières de ce criquet.

Nous étions bien étonnés du faible développement des associations riveraines. Est-il dû aux causes primaires ou secondaires ? Cela nous a resté inconnu. Cette question, qui a une grande importance pratique, doit être étudiée spécialement.

(d) *Les steppes septentrionales de l'Iraq.*

Cette partie a été explorée par nous plus soigneusement que les autres parties de l'Iraq en liaison avec la question des sauterelles. Cette partie de l'Iraq non montagneuse est beaucoup mieux arrosée que les précédentes et présente dans des localités non cultivées un steppe qui devient de plus en plus riche dans la direction de S. au N.

L'aspect printanier est dominé dans une grande partie du Liwa de Mosul (où nous l'avons étudié le mieux) par une végétation courte et serrée (le degré de couverture du sol est de 80-90%), dont les composants principaux sont à peu près comme dans le Désert Syrien, mais la durée de vie est plus longue. C'est une association ou plutôt l'aspect printanier d'une (ou de plusieurs) association à *Poa bulbosa*—*Carex stenophylla*—*Ranunculus asiaticus*, que nous appellerons plus loin P.-C.-R. (Pls. ix, xi). L'aspect estival est de hautes herbes pérenniales, qui dans leurs stades jeunes forment un ensemble avec l'association de P.-C.-R., mais plus tard, quand ce dernier est fané, à peu près depuis mi-mai, forment un steppe plus ou moins ouvert, mais beaucoup plus développé et gai que le steppe estival du Désert Syrien, autant que ce steppe existe là. Autant par leur écologie que par leur composition floristique, ils se diffèrent grandement. Mais aussi ce steppe, après que ces hautes herbes ce sont fanées, doit présenter un aspect bien triste, un aspect désertique. Cet état nous ne l'avons pas vu nous-mêmes.

Nous pûmes étudier à maintes reprises la genèse de la végétation de ce steppe. Les champs cultivés, délaissés 2-3 années, commencent à se couvrir (si les conditions édaphiques sont favorables) de petits îlots de P.-C.-R. Leur origin n'est pas encore suffisamment claire et nécessite l'étude spéciale. Ces îlots se serrent de plus en plus et forment à la fin une couverture plus ou moins continuée et serrée. En même temps, les plantes pérenniales, qui ne sont jamais complètement déracinées par la méthode primitive du labourage en Iraq, reprennent bien vite la place perdue par le labourage et commencent, en se développant, à reprendre place aussi à P.-C.-R., jusqu'à ce qu'un équilibre naturel est atteint. Les détails de ce processus nous sont restés naturellement encore inconnus, et leur connaissance a un grand intérêt pour la lutte offensive contre les sauterelles. Le développement typique de P.-C.-R. est lié avec des conditions écologiques (surtout édaphiques) bien nettes, et nous en parlerons plus tard.

Cette partie de l'Iraq, y compris les sylvo-steppes limitrophes du Kurdistan iraquien, est le centre pour les champs de ponte permanents des sauterelles marocaines.

(e) *Le Kurdistan Iraquien.*

Une série de chaînes de hautes collines et de montagnes de 700-1,300 m. au moyen, qui ont leur direction principale de N.-W. à S.-E., séparées par tout un système de vallées et plaines de 500-800 m. d'altitude, qui forment ensemble le Kurdistan Iraquien, a une végétation bien distincte de la végétation des parties

dont nous sommes occupés plus haut. Les associations climatiques y sont arbustives. C'est la seule partie de l'Iraq non steppique et non désertique. Les différents chênes à feuilles caduques y régissent, et tous les autres composants de ces forêts sont également à feuilles caduques. C'est un type des forêts irano-touraniennes (Eig 1931).

Nous avons pénétré le Kurdistan par trois points et nous avons atteint les premiers avant-coureurs des forêts quelques 65 km. E. de Kirkuk à l'altitude de 900 m., 25 km. N.-E. d'Arbil à l'altitude de 820 m., et 70 km. au N. de Mosul à l'altitude de 550 m. A mesure qu'on avance de S. à N. les forêts apparaissent dans une altitude de plus en plus basse. La saison étant encore peu avancée, nous ne pûmes étudier les différents types des forêts. La seule exception présente une forêt de pins que nous avons étudiée à Zawita, à l'E. de Dohuk. C'est un type étranger aux conditions écologiques générales du Kurdistan, et paraît être une enclave méditerranéenne au milieu des conditions irano-touraniennes. L'exploration géobotanique du Kurdistan, base de reboisement rationnel, est encore tout à faire.

Le Kurdistan iraquien est soumis presque tout entier aux invasions des sauterelles marocaines. Mais il n'y a pas de doute qu'il soit en dehors des champs de ponte permanents.

3. La végétation et les sauterelles et quelques notions spéciales concernant leur ensemble.

Arrêtons nous tout d'abord brièvement sur le dynamique d'expansion des sauterelles marocaines (*Doclostaurus maroccanus*, Thunb.). En certaines années elles apparaissent en grandes masses et envahissent des pays entiers (par exemple toute la partie septentrionale de l'Iraq, presque toute l'Asie Mineure etc.). Dans ces années d'expansion la ponte s'est faite sur des surfaces très vastes, soumises aux conditions écologiques bien diverses, mais même alors ne sortant pas des limites climatiques définies. Ces limites sont des *limites macroclimatiques maximales*, qui régissent l'expansion des sauterelles. En Iraq, par exemple, cette limite passe dans la direction méridionale à peu près par Baghdad (Uvarov 1933, fig. 1; Dutt, oralement). En Asie Mineure la limite septentrionale est la zone maritime de la Mer Noire (Uvarov 1932, fig. 2).

Au bout de quelques années le reflux commence. La zone d'invasion se rétrécit pour arriver à un minimum plus ou moins constant pour quelques années. Ce minimum sera la *zone macroclimatique optimale* pour le développement des sauterelles, que nous appellerons, d'accord avec Uvarov (1932, 1933), la *zone des réserves*.

Puisque le terme "réserve" n'était pas toujours employé par B. P. Uvarov (1932, 1933) rigoureusement dans le même sens, j'ai cru utile, d'accord avec Uvarov (*in litt.*) de préciser à nouveau cette notion fondamentale. Les *réserves* ("reservations" en anglais), ou "*les champs de ponte optimaux potentiels*" sont des localités dans la "zone macroclimatique optimale" où la ponte des oeufs se fait ou peut se faire, d'une façon régulière même dans les années du minimum de reflux des sauterelles. Ce sont des foyers d'expansions.

Les réserves (champs de ponte optimaux potentiels) sont réglés tout d'abord par les facteurs édaphiques majeurs. Quoique la composition chimique du sol joue parfois un grand rôle, ce sont surtout ses propriétés physiques qui paraissent être importantes. Ces propriétés sont déterminées aussi bien par la mode de genèse du sol (son origine et la manière de sa formation) que par l'action récente de l'homme (terre labourée ou non labourée, surpâturée etc.).

Puis les réserves dépendent des facteurs climatiques et édaphiques mineurs (microécologiques) bien déterminés (exposition, inclinaison, degré de couverture par des pierres etc.).

Ainsi, les immenses plaines de Djezireh, malgré qu'elles soient situées dans la zone macroclimatique optimale pour le développement des sauterelles marocaines, ne contiennent point, ou en contiennent à peine, des réserves, le sol étant, paraît-il, trop poreux et meuble.* Les champs de ponte optimaux (les réserves) dans ces parages sont concentrés presque exclusivement sur des chaînons des collines et de petites montagnes ou de petits "tels" qui parcourent ci et là ces immenses plaines, mais surtout les bordent. Le sol y est généralement très compact, pierreux et caillouteux. Au N.-E. de Mosul p. ex., une pareille concentration des réserves se trouve sur le Jebel Atchan, un petit chaînon de hautes collines, qui possède à la fois les conditions macroclimatiques et macroédaphiques propices pour les champs de ponte des sauterelles. Mais dans le Jebel Atchan lui-même les champs de ponte optimaux sont répartis très inégalement, dépendant de l'exposition, d'inclinaison, de couverture en grandes pierres, du degré de couverture par des cailloux etc.

Il est évident qu'il faut bien distinguer "les champs de ponte optimaux potentiels" (les réserves) des champs de ponte de la zone d'invasion. Les premiers sont strictement liés à la zone des conditions macroécologiques optimales pour le développement des sauterelles et sont pratiquement des localités dont la connaissance est nécessaire pour mener à une bonne fin la lutte offensive contre les sauterelles. Les derniers se trouvent en dehors de ces conditions favorables et ne présentent qu'un intérêt secondaire.

Dans la lutte offensive contre les sauterelles on a affaire non aux "champs de ponte potentiels" mais aux "champs de ponte effectifs (actuels)," des localités où les oeufs sont pondus effectivement. Quant aux relations entre "les champs de ponte optimaux effectifs" et les "champs de ponte optimaux potentiels" elles sont réglées à un certain point par des conditions dont nous parlerons plus tard, mais en général par le pur hasard.

Quelles que soient les conditions qui provoquent le passage du stade solitaire des sauterelles au stade d'essaim et le commencement de la période d'invasion (Uvarov 1932), l'importance de la connaissance des points de départ des invasions périodiques est tout-à-fait évidente, et ce point est bien accentué par Uvarov (1932, 1933). Le problème se pose donc d'une manière bien nette : il faut étudier les champs de ponte dans un nombre d'années le plus grand possible et tâcher de reconstituer autant que possible exactement le tableau d'invasion des sauterelles. Puis en étudiant un nombre maximal des "champs de ponte optimaux effectifs" il faut circonscrire la zone des réserves (champs de ponte optimaux potentiels), arriver aux conclusions générales concernant leur écologie et végétation et trouver une méthode autant que possible sûre, commode et facile pour pouvoir circonscrire pratiquement dans un nombre d'années limité les champs de ponte potentiels, afin d'ouvrir une lutte offensive la plus économique et la plus effective.

C'est l'étude de la végétation qui peut, comme il paraît, répondre de la meilleure manière à ces exigences. Puisque à chaque complexe des conditions écologiques correspond une végétation particulière, et au contraire à chaque type de végétation correspondent des conditions écologiques bien précises (Eig 1932), il suffit d'étudier la végétation de ces champs de ponte effectifs pour trouver les indicateurs nécessaires. C'était le point de départ théorique dans nos recherches consacrées à l'étude de la végétation du Liwa de Mosul, Liwa soumis, peut-être plus que des autres, au danger permanent des sauterelles. Ce point de vue a été éveillé et a été défendu par B. P. Uvarov, le meilleur spécialiste des sauterelles, à qui je suis bien reconnaissant de m'avoir intéressé à cette question attractive de la biologie générale.

* Même dans les parties non labourées depuis de longues années et où la végétation naturelle est complètement rétablie.

Dans son rapport préliminaire sur les investigations des sauterelles dans le proche Orient en mai-juin 1932, Uvarov dit : " More detailed ecological studies can produce good practical results only if they rest on a solid foundation of botanical knowledge. It appears essential therefore, that at least a preliminary botanical survey of the infested zone should be made without delay." Dans un article consacré à l'écologie des sauterelles marocaines en Anatolie occidentale (1932) Uvarov explique d'une manière courte quelle est la portée pratique de l'exploration de la végétation pour la question de la lutte contre les sauterelles : " The natural vegetation of reservations represents a feature relatively easy to study, and it can be correctly considered as a true index to a number of other factors more difficult to observe, such as soils and climate." Et en effet dans l'article cité comme aussi dans son dernier article (1933) Uvarov consacre beaucoup de place à la végétation des pays discutés.

4. La composition et les exigences écologiques de *Poa bulbosa*—*Carex stenophylla*—*Ranunculus asiaticus*.

Nos investigations ont révélé, que les champs de ponte de *Dociostaurus maroccanus* sont liés, au moins dans le Liwa de Mosul, intimement avec *P.-C.-R.*, qui est généralement le stade printanier de l'association *Philomis Bruguieri*—*P.-C.-R.* (Pl. ix).* Parmi les 22 " relevés " que nous avons pris dans les champs de ponte des sauterelles, aussi bien de cette année (15) que des années précédentes (7), nous avons trouvé un seul en dehors du développement typique de cette association.† Cette association présente donc le plus grand intérêt pour l'étude de l'écologie des champs de ponte des sauterelles. Quelle est son écologie ? A quel point cette association pourra-t-elle nous servir d'indicateur des champs de ponte optimaux des sauterelles ?

Nous sommes seulement au commencement des recherches dans cette direction, et il faut développer encore un grand effort zoobotanique avant que nous puissions éclaircir d'une manière suffisante cette question. Mais quoique notre voyage n'ait été qu'un voyage de reconnaissance et quoique le temps nous ait manqué de mettre en ordre d'une manière suffisante toutes les notes et tous les matériaux apportés qui concernent cette question, nous pouvons déjà indiquer quelques points intéressants concernant le travail futur. Nos discussions ci-dessous concernent seulement le Liwa de Mosul, où nous avons étudié, quoique sommairement, la question des sauterelles nous-mêmes et sur place. Nous consacrerons aussi à la question des sauterelles en dehors du Liwa de Mosul quelques pages à la fin de ce chapitre. Pour être prudents nous basons nos discussions presque exclusivement sur " les champs de ponte effectifs " et non sur " les champs de ponte potentiels." Nous nous basons sur les 15 relevés dans des champs de ponte de cette année et sur 7 dans des champs de ponte des années précédentes, aussi bien que sur les observations nombreuses dans des champs de ponte de cette année ou des années précédentes, dont la végétation n'était pas prélevée exactement, et finalement sur l'étude dans notre laboratoire de nombreux échantillons des champs de ponte, apportés avec nous.

* Depuis que mon rapport a été envoyé au gouvernement iraquien j'ai reçu, grâce à l'amabilité de B. P. Uvarov, trois travaux concernant les sauterelles marocaines : De Sviridenko " Observations biologiques sur la sauterelle marocaine " (en russe, 1924) et de S. Zhdanov, " La sauterelle marocaine dans la province du Stavropol " (en russe 1934), les deux traitant cette sauterelle au Caucase et Turkestan, et de R. Pasquier " Contribution à l'étude du criquet marocain en Afrique Mineure " (1934). Par ces travaux j'ai pu apprendre, que la végétation des champs de ponte en Algérie d'un côté, et au Caucase et Turkestan de l'autre, a beaucoup de ressemblance avec celle de l'Iraq. *Poa bulbosa* joue partout un rôle important. Ma supposition, que par son écologie *Dociostaurus maroccanus* est un insecte irano-touranien trouve sa confirmation dans ces travaux. Il est vraiment regrettable que je n'ai pas eu connaissance du travail de Sviridenko, paru encore en 1924, avant mon départ pour Iraq.

† J'emploierai généralement le terme " association " en parlant aussi seulement de *P.-C.-R.*, bien que plus exactement il faille préciser en employant un terme un peu plus long : " l'aspect printanier de l'association."

La couverture du sol par ces plantes est 75-95%, le plus souvent 80-85%. Sauf une ou deux exceptions la *Poa* et la *Carex* elles seules ont couvert au moins la moitié de la surface générale du sol, *Poa* étant généralement plus nombreuse. Dans les 22 relevés pris, *Poa* et *Ranunculus* n'ont manqué jamais. *Carex* a manqué dans 3 cas.

Les satellites annuels ou géophytes de cette association sont très nombreux, mais seulement quelques-uns sont plus ou moins constants. Suivant la position géographique, l'altitude etc. ces satellites révèlent des différences écologiques plus fines que l'écologie globale révélée par le P.-C.-R. L'étude de ces différences présente une tâche bien compliquée, mais des plus intéressantes pour le problème qui nous occupe.

Le réveil à la vie de P.-C.-R. au printemps se fait très tôt. Il paraît, qu'une légère pluie, ou peut-être même un simple abaissement prolongé de la température, suivi d'une augmentation considérable de l'humidité relative, suffit pour commencer à éveiller à la vie nouvelle les touffes de *Poa*. En tout cas, P.-C.-R. atteint son plein développement vers le temps de l'éclosion des jeunes sauterelles.

P.-C.-R. se développe normalement seulement sur un sol bien compact. Les facteurs édaphiques jouent un rôle très important dans le développement de P.-C.-R. Il y a peu à douter que les systèmes radicaux de deux édificateurs principaux de cette association, de *Poa* et de *Carex*, ne déterminent en grande partie ces exigences. Les racines de *Poa* sont courtes et minces, mais très denses (Pl. x, fig. 3; xi, fig. 1). Ce système radical exige l'humidité dans la couche supérieure du sol, chose atteinte plutôt dans des sols compacts que meubles et sablonneux.

Quant à *Carex* avec la ramification riche mais superficielle de ses rhizomes (Pl. x, fig. 3; xi, fig. 2), elle a son optimum du développement dans des dépressions où se ramasse une quantité d'eau suffisante pendant l'hiver. Là *Carex* forme des grandes tâches presque pures comme beaucoup d'autres de ses congénères. Mais justement dans ces conditions nous n'avons jamais rencontré des sacs des oeufs. Les places préférées pour la ponte des oeufs se trouvent là où *Carex* pousse en petites colonies, qu'indiquent d'un côté une humidité suffisante, mais de l'autre côté aussi la discontinuité de ces conditions humides et le drainage naturel. Il paraît que le drainage naturel soit bien important pour le développement optimal de P.-C.-R. Le beau développement de cette association sur les légères pentes paraît être lié avec ce facteur (Pl. ix).

Le système radical du troisième composant principal de P.-C.-R., de *Ranunculus asiaticus* (Pl. xi, fig. 3), se développe à peu près dans la même couche du sol que les rhizomes de la *Carex*. Mais les exigences édaphiques de cette plante nous sont restées peu connues. Nous n'avons pas eu l'occasion de l'observer, comme les deux premières plantes, sur des surfaces énormes, puisque pratiquement en Iraq nous ne l'avons rencontrée que dans le Liwa de Mosul et d'Arbil. Il ne faut pas se douter du rôle important de *Ranunculus asiaticus* comme indicateur des conditions écologiques très favorables pour la ponte des oeufs, et l'étude de sa biologie est un des premiers problèmes qu'il faut aborder.

Le système radical de P.-C.-R. ou plutôt de ses composants principaux, de *Poa* et de *Carex* et peut-être aussi de *Ranunculus*, en dehors d'être des causes principales des exigences édaphiques de P.-C.-R., est lié, paraît-il, avec un autre fait important. Etant très dense et ayant sa "couverture" générale toujours beaucoup plus grande que celles des parties aériennes de la plante, ce système radical, il y a peu à douter, crée des conditions édaphiques spéciales (Pl. x, fig. 3). Un des points des plus importants dans la considération de P.-C.-R. est de savoir s'il y a des relations directes entre les conditions écologiques spéciales créées par ce système radical et la conservation des oeufs et l'éclosion optimale des jeunes sauterelles. Si oui, P.-C.-R. ne sera plus seulement un indicateur passif des conditions écologiques propices pour le développement des oeufs, mais aussi lui-même un facteur actif favorable. En

tout cas, l'explication de La Baume (1918) que les champs de ponte sont déterminés seulement pour le mécanisme de la ponte, me paraît être bien insuffisante. Sans doute, la nécessité d'un terrain compact pour l'acte de la ponte est très probable. Mais il y a peu à douter, que les exigences édaphiques liées à l'acte de la ponte ne soient les seuls facteurs déterminatifs. Les exigences édaphiques optimales pour la conservation et pour le développement des oeufs jouent, paraît-il, le rôle principal dans le choix des champs de ponte.

Dans le Liwa de Mosul P.-C.-R. se développe le mieux sur le sol peu ou pas du tout caillouteux à l'intérieur et généralement seulement légèrement pierreux ou caillouteux ou pas du tout sur la surface. Mais des grandes pierres et des roches sont dispersées souvent ici et là, sans jouer, paraît-il, aucun rôle important dans la création des conditions édaphiques des champs de ponte (Pl. ix, fig. 2). L'assertion que les champs de ponte des oeufs sont des localités bien caillouteuses ne me paraît pas être exacte, au moins pas pour le Liwa de Mosul. Les terrains sablonneux ne sont pas favorables pour le développement de P.-C.-R., non plus les terres trop gypseuses. Ce sont des facteurs négatifs pour le développement de P.-C.-R. et en conséquence aussi négatifs pour la formation des champs de ponte des oeufs.

5. Les places préférées pour la ponte des oeufs.

Toutes les localités typiques pour la ponte des oeufs, que nous avons visitées, ont montré invariablement l'arrangement tacheté. Par cela j'entends, que les petites tâches de l'association de P.-C.-R. typiques sont mélangées aux petites tâches non typiques de P.-C.-R., où le pourcentage des plantes annuelles est beaucoup plus élevé par espèces et par nombre d'individus. Généralement un fort contingent de plantes rudérales ou rudérales-ségétales s'y concentre. Ces dernières tâches saillent par leur verdure plus luxuriante et plus dense. Les oeufs sont pondus, presque invariablement dans les tâches de P.-C.-R. typiques, surtout parmi les touffes maigres de *Carex*, tandis que les tâches de P.-C.-R. non typiques, à la végétation plus luxuriante, sont des places de concentration des sauterelles dans les premiers jours de leur vie, ce sont les "salles à manger" (Pl. ix, fig. 2) des jeunes sauterelles, par contre aux tâches typiques de P.-C.-R., qui sont des "chambres à coucher" ou plutôt "de naissance." Uvarov parle aussi (1932) de la disposition tachetée des places de l'oviposition, bien que dans un sens un peu différent.

6. L'aspect estival de l'association *Phlomis Bruguieri*—P.-C.-R.

Je ne parle pour le moment que de P.-C.-R. Mais il n'y a pas à douter, que P.-C.-R. ne soit seulement une partie de l'association ou des associations typiques pour les champs de ponte optimaux des oeufs. C'est leur aspect printanier. Quant à l'aspect estival, les composants les plus importants sont *Phlomis Bruguieri*, *Gundelia Tournefortii*, *Ornithogalum ulophyllum* et *Cousinia stenocephala*. *Hypericum crispum*, *Gagea reticulata* et *Prosopis Stephaniana* sont aussi assez caractéristiques. Pour cette dernière plante je suis en désaccord avec Uvarov (1933) qui en parle comme "definite negative indicator."

Si pour l'étude de développement et même de la genèse de P.-C.-R. nous avons obtenu déjà des résultats très précieux, notre connaissance des relations de P.-C.-R. au stade estival de l'association de *Phlomis Bruguieri*—P.-C.-R. et de la genèse générale de l'association entière est encore presque nulle. Ici tout est encore à faire.

7. La question de la végétation naturelle nécessaire pour le cycle complet du développement des sauterelles.

Une question qui me paraît avoir un intérêt théorique et pratique est la suivante : quelles sont les conditions naturelles du cycle de développement des sauterelles en dehors des conditions artificielles que l'homme a créées par ses champs des céréales ?

Existent-elles dans le Liwa de Mosul ou partout ailleurs en Iraq ou dans les parties limitrophes des pays voisins des localités en dehors de la zone des cultures et où les sauterelles passent toutes les phases de leur vie d'une manière permanente ?

Dans les rapports qui traitent de la lutte contre les sauterelles et couvrent la période 1923-1929 et qui m'ont été prêtés aimablement par Monsieur Muhammad Effendi ar-Râdhi, le Directeur du Service de la protection des plantes, nous trouvons quelques passages qu'on pourrait désigner comme une réponse positive à ma question. Malheureusement ces données sont vagues et n'apportent pas la certitude voulue. Cette question n'est pas non plus claire dans le Rapport de 1933 de B. P. Uvarov ; il y a touché dans le passage traitant le Djézireh. Non plus dans le " Bull. de l'Office international " de renseignements sur les sauterelles de Damas, consacré aux invasions de 1930-1931. Quant à moi-même, pour le moment une réponse directe m'est impossible.

Dans notre traversée Khanaq-Mosul nous avons trouvé 2 à 3 fois des sacs des oeufs anciens éloignés au moins 10 à 15 km. des champs de culture. Il est très possible que ce soient les champs de ponte de la dernière grande expansion des sauterelles en 1929. Il n'y a pas à douter que le développement des jeunes sauterelles ne se soit fait ici tout entièrement dans le steppe naturel, mais il paraît, que les insectes ailés se soient envolés vers les cultures bordant le Tigre.

La végétation du grand steppe, que nous avons traversé, a été composée tout spécialement des trois associations que nous nommerons provisoirement les associations à *Phlomis Bruguieri*, à *Phlomis orientalis* et à *Centaurea Behen*. La première d'elles occupe généralement des localités plus élevées du sol compact ; la deuxième généralement des espaces plats au sol mou, et la troisième les dépressions au sol compact. Le développement de ces associations paraît aussi être un peu différent. Le stade printanier à P.-C.-R. se développe optimalement seulement dans l'association à *Phlomis Bruguieri*. Et c'est ici seulement, que nous avons trouvé les sacs aux oeufs dans le steppe naturel. La préférence de P.-C.-R. pour la ponte a été ici particulièrement claire. Le cycle de développement des sauterelles ici paraît être le suivant : Les oeufs sont posés et se développent dans le P.-C.-R. de l'association de *Phlomis Bruguieri*—P.-C.-R., et les jeunes sauterelles se nourrissent dans les premiers jours de leur développement de P.-C.-R. Puis la migration commence et les sauterelles se nourrissent d'abord des composants herbeux des trois associations mentionnées plus haut, et quand celles-ci disparaissent, des rosettes de *Phlomis*, de *Centaurea*, de *Gundelia* et d'autres composants de l'aspect estival de ces associations et plus tard de ces plantes déjà développées. Vraisemblablement les sauterelles n'atteignent qu'en état ailé la zone cultivée.

Il n'y a peu à douter, que dans le Liwa de Mosul les sauterelles ne préfèrent les champs cultivés à la végétation estivale naturelle. L'observation de La Baume (1918), qu'en Asie Mineure—au moins pendant un certain âge—elles visent plutôt aux plantes ségétales (mauvaises herbes) qu'aux cultures elles-mêmes, est très intéressante. En tout cas, je ne vois que deux possibilités pour expliquer la migration des sauterelles du steppe vers les champs cultivés : ou bien les champs cultivés ont remplacé la végétation naturelle—une sorte de prés, comme il paraît—qui est nécessaire pour compléter le cycle naturel optimal du développement des sauterelles ; ou bien le Liwa de Mosul ne se trouve pas encore dans l'optimum des conditions naturelles pour le développement des sauterelles ; cet optimum se trouve alors quelque part plus au nord ou au N.-W. Remarquons, que dans le " Bull. de l'Office intern. " de Damas consacrés aux invasions de 1930 et 1931 les auteurs disent (p. 218) : " Il est établi définitivement que la zone permanente qui constitue le foyer principal de propagation de cette espèce (*Stauronotus maroccanus*) dans les territoires des états adhérents à l'office est Djézireh (régions situées entre l'Euphrate et le Tigre, entre le 36 et 37° du lat. Nord) c.a.d. justement dans le Liwa de Mossul."

Je voudrais encore ajouter, que d'après tout ce que j'ai pu apprendre pour le moment des sources littéraires et de mes propres observations, *Doclostaurus maroccanus* paraît être un insecte irano-touranien (Eig 1931) (quoique déjà à la limite des conditions méditerranéennes), un insecte steppique, mais aux conditions de steppes qui limitent déjà les conditions des associations forestières (voir aussi Uvarov 1933 et les cartes des invasions de 1930 et 1931 dans le Bull. de l'office de Damas cité plus haut).

L'existence des associations des types des prés, surtout des associations des prés riverains, que nous avons présumé plus haut comme devant entrer dans la composition générale de la végétation primitive du Liwa de Mosul, paraît être tout à fait possible dans l'aire naturelle des sauterelles.

J'ai éveillé cette question ici, puisqu'elle a non seulement un intérêt théorique, mais aussi pratique.

8. La végétation et les sauterelles en dehors du Liwa de Mosul.

Je n'ai pas étudié spécialement la question des relations entre la végétation et les sauterelles en dehors du Liwa de Mosul. Mais grâce aux 32 échantillons des champs de ponte, reçus du Directeur du Service de la protection des plantes, et à nos notes et à nos matériaux concernant la végétation du Liwa d'Arbil et du Liwa de Kirkuk que nous avons rapportés avec nous, aussi bien que grâce aux informations très utiles, dispersées dans les comptes rendus annuels de la lutte contre les sauterelles du gouvernement d'Iraq, je peux dès maintenant envisager à un certain point la question de la biocoenose "végétation—sauterelles" en Iraq en général. Tous les échantillons des champs de ponte du Liwa d'Arbil appartiennent à l'association de P.-C.-R., quoique généralement non typiques. Mais seulement peu parmi ces échantillons appartiennent à la même catégorie des sols des champs de ponte que j'ai étudiés dans le Liwa de Mosul. Le sol est ici plus désertique qu'au Liwa de Mosul et possède sans doute d'autres caractères écologiques que le sol de Mosul.

Les échantillons du Liwa de Kirkuk montrent aussi un sol bien différent de celui du Liwa de Mosul, encore plus désertique. Par leur végétation ils n'appartiennent plus à l'association de P.-C.-R., même que *Poa* y soit presque toujours bien représentée. Non seulement l'absence de *Ranunculus asiaticus* est très caractéristique, mais surtout de *Carex stenophylla*. Par leur composition floristique elles appartiennent généralement encore plutôt à un type irano-touranien steppique qu'irano-touranien désertique, mais deux à trois sont déjà distinctement d'un type irano-touranien désertique avec l'influence saharo-sindienne (Eig 1931). Les conditions écologiques y paraissent être bien différentes de celles du Liwa de Mosul.

Les échantillons de Khaniqin appartiennent par leur végétation non plus à une P.-C.-R. typique et présentent aussi un type de passage entre la végétation irano-touranienne steppique et irano-touranienne désertique. Le sol est plutôt désertique que steppique.

Les échantillons de Sulaimani saillent immédiatement par leur sol noir, riche en humus, qui n'a rien de semblable au sol de Mosul. Il n'y a pas à douter que des conditions climatiques tout à fait autres que celles du Liwa de Mosul n'aient formé ce sol. Mais ces échantillons nous n'intéressent pas, puisque je n'y ai pu trouver pas du tout des sacs aux oeufs, et il paraît, que la personne qui les a prélevés se soit trompée.

Nous voyons donc, que jugeant d'après ces échantillons la végétation et le sol dans le Liwa de Kirkuk et aux environs de Khaniqin sont bien différents de ceux du Liwa de Mosul, et même dans le Liwa d'Arbil le sol, au moins, est différent. Il est bien naturel, que les conditions de conservation et de développement des oeufs dans ces conditions différentes varient beaucoup. Nous faut-il en conclure, que la biocoenose P.-C.-R.—sauterelles dans le Liwa de Mosul est un phénomène local, qui n'est pas la seule expression des meilleures conditions pour le développement

des oeufs, et que partout ailleurs en Iraq il faut chercher une autre combinaison ? Les investigations futures nous le montreront.

En tout cas nous avons obtenu les résultats les plus intéressants de l'étude comparative des échantillons des champs de ponte du Liwa de Mosul, rapportés avec nous d'Iraq, et des échantillons des Liwas d'Arbil, de Kirkuk et Diala, reçus du Directeur du Service de la protection des plantes. Il nous faut seulement regretter, que par le manque de temps (l'étude détaillée des échantillons des champs de ponte exige beaucoup de temps du personnel technique et scientifique) nous pûmes étudier en détail le système radical seulement d'une partie des échantillons.

Le fait le plus important, que le lavage du système radical des échantillons a découvert, est, que le nombre des sacs aux oeufs dans la terre est souvent beaucoup plus grand que le nombre des trous qu'on voit en examinant la superficie de la terre. Ma première pensée a été que seulement les trous des sacs aux oeufs de l'année courante sont visibles à la surface de la terre et que les pluies de l'hiver des années passées, entraînant des particules de la terre, ont fermé les trous béants. Les échantillons du Liwa de Mosul que nous avons étudiés ont montré après le lavage, sauf deux exceptions, un nombre de sacs dans le sol de 6 à 10 fois plus grands que le nombre des trous béants. Dans les autres échantillons la différence était moins marquée, mais aussi très saillante.

En examinant attentivement les vieux sacs aux oeufs, on arrive à la conclusion que ces sacs proviennent d'âges différents. Y a-t-il une relation directe entre le degré des décompositions des sacs et le nombre d'années qu'ils se trouvent dans la terre ? Cela se peut. C'est une question d'une grande importance, d'étudier la décomposition des sacs à la longue. Nous avons à regretter notre ignorance de cette question encore pendant notre visite au Liwa de Mosul. Après avoir découvert la liaison de la ponte et de P.-C.-R., nous avons essayé maintes fois de chercher les anciens sacs dans des localités de P.-C.-R. typiques, non infestées cette année, et il faut dire, très souvent avec succès. Malheureusement, n'étant pas expérimentés dans la connaissance de l'âge des vieux sacs, nous ne pûmes, même pas approximativement, fixer l'année de la ponte. Mais les moukhtars et d'autres gens du pays qui nous ont souvent accompagnés se vantaient de pouvoir fixer l'âge des vieux sacs. Je n'ai pas pu rectifier ces assertions, mais je ne doute pas, qu'une personne qui s'y intéressera sérieusement ne puisse arriver facilement aux conclusions pratiques et ne puisse donner une méthode à distinguer l'âge des vieux sacs aux oeufs. Si nous saurons distinguer l'âge des vieux sacs, nous arriverons, en étudiant attentivement les échantillons des champs de ponte, à avoir une méthode importante qui nous aidera à reconstituer l'histoire de la ponte dans cette localité pendant un nombre d'années limité. L'importance de ce fait pour la délimitation des réserves et des champs de ponte effectifs est évidente. Ajoutons, qu'Uvarov (*in litt.*) doute de la possibilité de reconnaître l'âge des vieux sacs aux oeufs.

Mais dès maintenant on peut tirer des conclusions intéressantes en employant cette méthode. Nous avons trouvé, que, sauf deux cas (dans un parmi ces deux cas nous n'avons pas trouvé des sacs aux oeufs du tout, et il paraît, que l'échantillon a été pris dans un champ de ponte potentiel et non effectif), les champs de ponte examinés du Liwa de Mosul possédaient au moyen presque une double quantité de sacs que les échantillons d'Arbil, et ceux d'Arbil une quantité nettement plus grande que celle du Liwa de Kirkuk et du Liwa de Diala.

Le nombre d'échantillons examinés étant trop petit, et surtout le doute que j'ai eu que les échantillons que j'ai reçus des localités en dehors du Liwa de Mosul, ne représentent pas toujours les localités typiques, ne permettent pas trop de généraliser les faits obtenus par le lavage des échantillons des champs de ponte. Aussi en feuilletant les comptes rendus annuels, traitant la lutte contre les sauterelles, on peut, paraît-il, recevoir l'opinion, que le Liwa d'Arbil est plus infesté que le Liwa de Mosul, mais il paraît que le nombre des dounams infestés ne soit pas en corrélation directe avec la constance de la ponte qui nous intéresse principalement.

Ainsi, les données du lavage des échantillons des champs de ponte, étant en accord avec d'autres données et raisonnements, me paraissent indiquer, que le Liwa de Mosul se trouve dans l'optimum de développement des sauterelles, et les Liwas de Kirkuk et Diala (Khanagin) se trouvent plutôt à la limite des conditions optimales. Uvarov, en se basant sur ses observations personnelles dans les Liwa de Kirkuk et Diala arrive à d'autres conclusions, dont je cite ici les points principaux d'après ses lettres :

" L'optimum des conditions pour les sauterelles n'est pas dans le Liwa de Mossul et non plus au N.N. ou N.-W. de ce Liwa, mais à l'E., dans le Liwa de Kirkuk et Arbil. On peut tirer cette conclusion en étudiant les vieilles cartes d'expansion et d'après le fait, qu'en 1932 j'y ai trouvé considérablement plus des places infestées par des oeufs des sauterelles qu'au Liwa de Mossul. . . . Et quant au Khanagin (Liwa de Diala), là les conditions sont encore plus désertiques comme vous l'écrivez avec justesse. Tout de même, sans doute on y trouve des réserves. . . ." (lettre de 23.xi.33).

" . . . Je suis sûr que la zone des réservations ne se termine pas même à Khanagin, mais se prolonge beaucoup plus au sud " (lettre de 28.ix.34).

En somme, les champs de ponte permanents optimaux pour tout l'Iraq paraissent ne pas dépasser, ou dépasser seulement peu, la zone du développement normal de P.-C.-R. Il est très probable, que les localités caillouteuses qu'Uvarov nomme dans son rapport optimales pour la ponte des oeufs, et dont dans le même sens a parlé le chef de la lutte contre les sauterelles à Kirkuk, soient des équivalents écologiques en quelque sorte, aux conditions de P.-C.-R. Mais je doute beaucoup que ces conditions ne soient vraiment des conditions optimales pour tout le cycle de développement des sauterelles. Les investigations futures nous renseigneront sur ce point important.

En même temps la reconstitution de l'histoire des invasions et des retraites des sauterelles en Iraq, au moins pendant les dix dernières années, me paraît être la plus utile. Les comptes rendus annuels des chefs de la lutte contre les sauterelles peuvent servir d'une des bases pour la reconstitution soit en traits bien généraux de l'histoire de l'expansion et retraite des sauterelles marocaines en Iraq pendant la dernière décade. Des renseignements, soigneusement menés sur place, et surtout l'étude d'un grand nombre d'échantillons de champs de ponte, peuvent compléter les données de ces comptes rendus. Ce travail doit se faire sans délai et avec tous les soins possibles.

9. Le résumé élargi sur la biocoenose végétation-sauterelles, surtout dans le Liwa de Mosul.

Ce n'est pas mon intention de donner dans ce rapport préliminaire tous les détails que j'ai pu obtenir pendant un court voyage dans le Liwa de Mosul sur la biocoenose *Phlomis Bruguieri*—P.-C.-R.—Sauterelles. D'ailleurs cela exigerait d'arranger et de déterminer dès maintenant toutes les plantes que nous avons rapportées de l'Iraq, et de mettre en ordre des autres matériaux, concernant ce problème, chose impossible pour le moment. J'ai discuté quelques faits un peu plus longuement, et maintenant je les résumerai en les complétant un peu.

Nous avons étudié la végétation des champs de ponte principalement dans le Liwa de Mosul, et nous y avons trouvé que P.-C.-R., le stade printanier surtout d'une association que nous nommerons pour le moment l'association de *Phlomis Bruguieri*—P.-C.-R., présente les conditions optimales pour le développement des oeufs des sauterelles. Il est bien possible, que non seulement P.-C.-R. soit l'indicateur d'un sol aux conditions écologiques propices pour le développement des oeufs, mais que son système radical très dense crée des conditions spéciales particulièrement favorables pour le développement des oeufs.

En Iraq, les espèces édifcatrices de P.-C.-R., *Poa bulbosa* et *Carex stenophylla*, ont une distribution beaucoup plus grande que les champs de ponte des sauterelles, même que les champs de ponte dans la région d'invasion. Par exemple, *Poa bulbosa*, *Carex stenophylla*—*Plantago ovata* est une association (ou souvent l'aspect printanier de quelques associations) qui domine une grande partie du Désert Syrien. Mais déjà le premier abord a montré que P.-C.-R. du Liwa de Mosul est bien différent de *Poa*—*Carex*—*Plantago* du Désert Syrien. La plante différentielle la plus importante est le *Ranunculus asiaticus*, mais aussi quelques autres plantes. L'étude approfondie de P.-C.-R. et des associations apparentées, où *Poa bulbosa* et *Carex stenophylla* jouent un rôle dominant, dans tout le territoire de l'Iraq (et même dans les contrées voisines), est un travail qu'il faut aborder immédiatement.

Ranunculus asiaticus paraît jouer un rôle secondaire dans la création des conditions édaphiques spéciales de l'association de P.-C.-R., mais pratiquement c'est une plante indicatrice par excellence. Ses grandes fleurs rouges, qui saillent de loin, sont les vrais indicateurs des "champs de ponte potentiels" dans le Liwa de Mosul. Nous étions bien surpris de rencontrer des indigènes qui connaissent par pratique le "Ward el Nissan" comme indicateur des champs de ponte.

Le peu que nous savons sur la végétation des champs de ponte en dehors du Liwa de Mosul paraît indiquer, que plus on s'éloigne au sud, la liaison entre les champs de ponte et P.-C.-R. devient moins claire, et il n'y a pas à douter qu'il existe des champs de ponte en Iraq en dehors de cette association. Mais autant que j'ai pu juger des rapports annuels de la lutte contre les sauterelles, de l'examen des échantillons des champs de ponte reçus et de ma connaissance de la flore d'Iraq, les champs de ponte au sud et à l'est des Liwas de Mosul et d'Arbil paraissent être déjà à la limite des réserves. Remarquons encore que d'après mes observations la P.-C.-R. typique ne se développe pas au sud d'Altun Keupri.

P.-C.-R. montre même dans le Liwa de Mosul des variations de composition, chacune possédant sa microécologie spéciale. Il y a peu à douter que les oeufs des sauterelles se développent différemment dans les variations différentes de P.-C.-R., et il est nécessaire d'étudier non seulement la composition floristique et l'écologie globale de P.-C.-R., mais aussi celles de ses variations.

En général, P.-C.-R. préfère des terrains compacts, peu ou non caillouteux (en dedans), bien drainés, non sablonneux, non salés et non trop gypseux.

P.-C.-R. atteint son plein développement vers le temps de l'éclosion des jeunes sauterelles et leur sert de nourriture. Mais généralement les propres places de ponte des oeufs, et les places où sont concentrées les herbes dont les jeunes sauterelles se nourrissent, sont éloignées quelques pas les unes des autres.

Les jeunes sauterelles montrent des préférences à certaines herbes, et il faut aborder cette question de près. La végétation de l'aspect estival de P.-C.-R. dans la zone des cultures ne sert généralement pas, ou sert seulement peu, de nourriture aux sauterelles, puisqu'elles atteignent généralement à la longue les champs cultivés. Mais dans des localités éloignées des champs de culture, les aspects estivals de *Phlomis Bruguieri*—P.-C.-R. aussi bien que d'autres associations steppiques forment la nourriture des sauterelles, après que la végétation printanière est fanée.

Tant que nous avons vu Djezireh, l'association de *Phlomis Bruguieri*—P.-C.-R. est répandue là moins que dans le reste du Liwa de Mosul. Dans une grande partie de Djezireh, que nous avons traversée, les conditions édaphiques ne sont pas favorables au développement de P.-C.-R. C'est un fait qu'il faut retenir, quand on fera le plan de la lutte rationnelle offensive contre les sauterelles dans l'Iraq. Uvarov parle aussi (1933) des mauvaises conditions édaphiques que présente la plus grande partie de Djezireh pour la ponte des oeufs.

Une question d'une grande importance, mais aussi pratique, est de savoir quelles sont les conditions d'un cycle entier du développement des sauterelles en dehors des champs de culture.

Par le labourage on détruit très facilement la P.-C.-R. Elle se reconstitue assez lentement. Des observations les plus exactes doivent être faites dans cette direction pour pouvoir introduire un labourage préventif effectif.

10. Suggestions et recommandations.

J'adhère aux excellentes recommandations générales proposées par B. P. Uvarov (1932) et surtout aux recommandations concernant la nécessité absolue d'une collaboration étroite dans la lutte contre les sauterelles des pays intéressés dans le Proche Orient, et la nécessité des relèvements annuels des champs de ponte à une échelle de 1/50000.

Dans la lutte offensive contre les sauterelles il faut tout d'abord fixer la zone macroclimatique optimale et pour ce but la méthode des bioclimatographes (bioclimagrammes) proposée par Uvarov (1932) est des plus intéressants. Les données climatiques pour ce but étant de la première nécessité, il faut créer sans délai des stations météorologiques dans les points les plus importants.

Puis il faut fixer les conditions macroédaphiques majeures optimales et enfin étudier les conditions microécologiques favorables à la conservation et au développement des oeufs et des jeunes larves. Les méthodes directes pour les études des conditions édaphiques et microclimatiques sont généralement compliquées et de longue haleine ; d'autant plus importantes paraissent être les méthodes indirectes de l'étude de la végétation comme indicateur de la biocoenose " Sauterelles-végétation." L'étude approfondie de la végétation est nécessaire aussi pour fixer son rôle comme facteur direct pour le développement des sauterelles.

Je propose donc encore ces quelques recommandations :—

(a) Pendant les investigations futures de la végétation des Liwas infestées par des invasions des sauterelles, des efforts spéciaux doivent être dirigés vers l'étude approfondie de l'aspect printanier de l'association *Phlomis Bruguieri*—P.-C.-R. et d'autres associations apparentées, où *Poa bulbosa* et *Carex stenophylla* entrent comme des espèces édificatrices. De cette manière on pourra s'approcher de la connaissance de l'extension et de l'écologie de P.-C.-R. typique et de ses variations différentes, de la connaissance des champs de ponte potentiels présumés.

(b) L'étude expérimentale du développement et de la biologie générale des trois composants principaux de P.-C.-R., de *Poa bulbosa*, *Carex stenophylla* et *Ranunculus asiaticus*, nécessaire pour comprendre la genèse de cette association.

(c) L'étude des conditions écologiques qui présentent les différents types du sol (surtout le sol des réserves) où les sauterelles posent leurs oeufs, aussi bien sur place que dans le laboratoire, et l'étude des conditions spéciales y créées par le système radical de P.-C.-R.

Ces études doivent se faire d'après un seul plan commun et en collaboration avec les études expérimentales, poursuivies par l'entomologiste, sur les conditions écologiques nécessaires à la préservation, au réveil de diapause et au développement des oeufs.

(d) Il faut tâcher de reconstituer autant que possible exactement l'image générale de l'expansion des sauterelles en Iraq depuis que la lutte organisée se fait, depuis qu'on possède ainsi des documentations diverses concernant ces invasions, et depuis qu'on peut, même maintenant, ramasser des informations complémentaires chez des employés divers qui ont participé à cette lutte. Le mieux serait de dresser des cartes annuelles des invasions passées, aussi bien de la ponte que de l'expansion des sauterelles ailées.

(e) L'expérience a montré que même les cartes de 1/50000 ne sont pas suffisantes pour l'étude exacte de la végétation et de l'écologie des champs de ponte effectifs. D'autre part les tas des pierres par lesquels on procède maintenant d'indiquer les

champs de ponte effectifs ne se conservent guère. J'ai proposé déjà pendant mon voyage d'introduire le système des petits piliers en béton, hauts à peu près d'un mètre, construits dans les quatre coins des champs de ponte. Je voudrais proposer que 200-300 champs de ponte effectifs de cette année dans toutes les parties de l'Iraq, soigneusement choisis pour couvrir des conditions écologiques différentes, soient marquées d'une telle manière. Les piliers en béton sont préférés, parce qu'ils donnent la garantie suffisante de n'être pas volés ou brisés. Ces champs de ponte marqués, auxquels on ajoutera les autres à l'avenir, si cela sera nécessaire, serviront de base exacte à l'étude de la microassociation et de la microécologie des champs de ponte en Iraq.

(f) L'expérience a montré aussi, que la méthode de prélever des échantillons des champs de ponte, afin de pouvoir les étudier dans un laboratoire, a donné de très bons résultats. Pour les contrées souffrant des sauterelles et se trouvant, comme cela se passe généralement, loin des centres des études dans les laboratoires de la question des sauterelles, cette méthode peut rendre des grands services dans la campagne organisée contre les sauterelles. Cette méthode nous donnera, paraît-il, aussi un nouveau moyen d'accélérer la circonscription des réserves. Il faut tâcher d'améliorer le mode de prélèvement et de transport des échantillons. Des centaines d'échantillons de toutes les parties de l'Iraq doivent être prélevés et étudiés à l'avenir proche. L'étude préliminaire des changements qui arrivent avec le temps dans les vieux sacs est une nécessité, et il ne faut pas l'ajourner.

(g) Une vingtaine de champs de ponte à P.-C.-R., couvrant les conditions macroclimatiques les plus différentes, seront labourés et marqués par les piliers de béton afin d'avoir une idée exacte du temps nécessaire pour la reconstitution naturelle de cette association. Le labourage de P.-C.-R. typique sera peut-être à l'avenir un des modes les plus effectifs dans la lutte offensive contre les sauterelles.

(h) L'expérience a montré que la végétation des champs de ponte est généralement tâchetée, les tâches où les oeufs sont pondus, alternant avec d'autres, généralement dans des très légères dépressions, à végétation plus riche et dense, où les jeunes sauterelles se ramassent dès les premiers jours de leur vie, pour se nourrir comme dans les "salles à manger."

Il serait utile, d'étudier les herbes préférées de ces "salles à manger" et le mode facile et à bon marché de les propager, afin d'essayer de créer artificiellement ou élargir ces points de centralisation des jeunes sauterelles, surtout dans des localités où le labourage est impossible ou difficile. Cela pourra faciliter la lutte contre les toutes jeunes sauterelles par la méthode d'arrosage à la solution empoisonnante. Il va sans dire que le premier essai doit se faire sur une toute petite échelle.

(i) Il faut mener des observations exactes aux champs, aussi bien que des simples expériences dans le laboratoire, sur la biologie des sauterelles marocaines en Iraq. Je ne suis pas la personne compétente pour indiquer le programme là-dessus, mais je voudrais suggérer tout de même quelques points suivants : la distance du déplacement pendant chaque âge, si les sauterelles sont dépourvues de nourriture ; la vitesse du déplacement pendant chaque âge ; la nourriture préférée dans les divers stades du développement etc.

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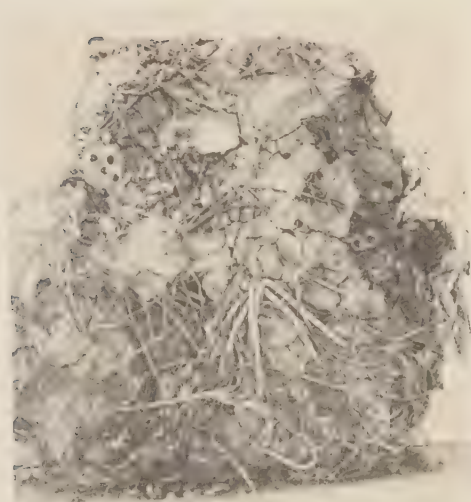
EXPLICATION DE PLANCHE IX.

Figs. 1 et 2. Photos typiques de l'association *Poa bulbosa*—*Carex stenophylla*—*Ranunculus asiaticus*. Remarquez les petites taches noires, présentant les fleurs de *Ranunculus asiaticus*.

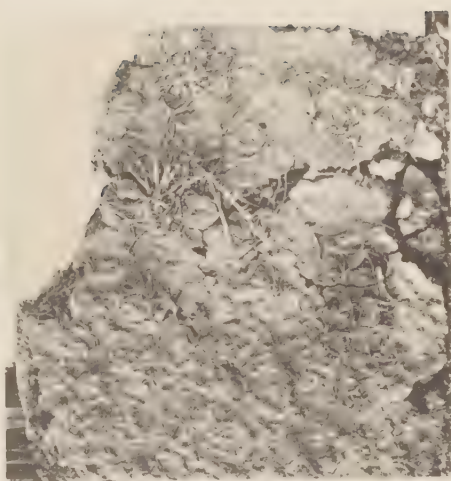


EXPLICATION DE PLANCHE X.

- Fig. 1. Les détails d'un champ de ponte à P.-C.-R. de Liwa de Mosul à dispersion normale de ses composants principaux. Notez les trous béants des sacs aux oeufs vides.
- Fig. 2. Un échantillon d'un champ de ponte de Khanaqin.
- Fig. 3. Echantillon des champs de ponte du Liwa de Mosul à P.-C.-R. montrant la position des sacs aux oeufs parmi les racines et les rhizomes.



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EXPLICATION DE PLANCHE XI.

Fig. 1. *Poa bulbosa*, L.

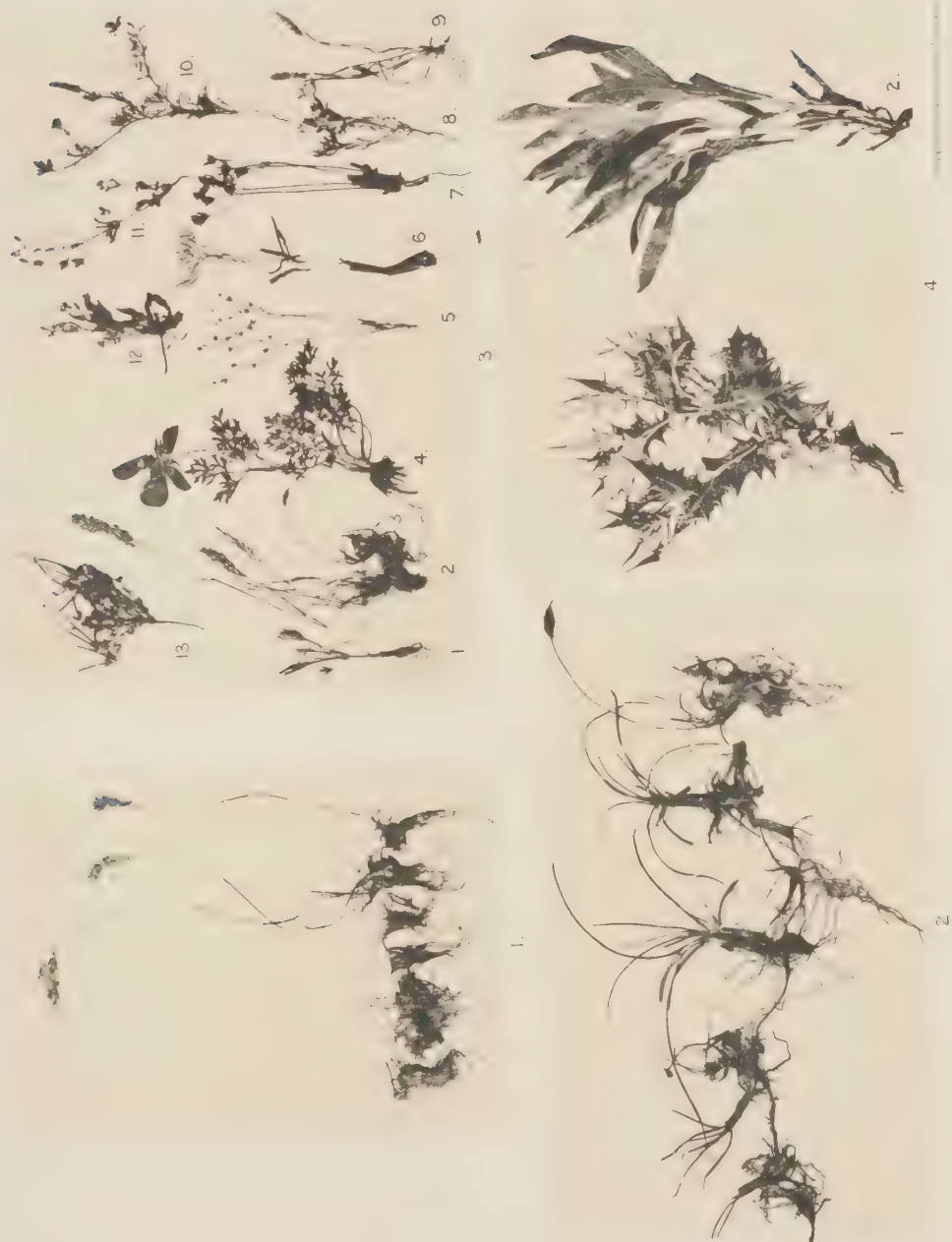
Fig. 2. *Carex stenophylla*, Wahlenb.

Fig. 3. Les espèces principales de P.-C.-R.

1. *Gagea reticulata* (Pall) Sch.
2. *Poa bulbosa*, L.
3. *Carex stenophylla*, Wahlenb.
4. *Ranunculus asiaticus*, L.
5. *Minuartia picta* (S. et S.) Bornm.
6. *Ornithogallum ulophyllum*, Hand. Maz.
7. *Lagoseris bifida*, L.
8. *Filago spathulata*, Presl.
9. *Koeleria phleoides*, Pers.
10. *Adonis dentata*, Del.
11. *Helianthemum salicifolium* (L.) Mill.
12. *Garrhadiolus hedyphnois* (F. et M.) Jaub. et Sp.
13. *Erodium cicutarium* (L.) L'Hér.

Fig. 4. Deux des composants principaux de l'aspect estival de *Phlomis Bruguieri* P.-C.-R. en état jeune.

1. *Cousinia stenocephala*, Boiss.
2. *Phlomis Bruguieri*, Desf.



FERTILITY AND TOLERATION OF LOW TEMPERATURE IN *EUCHALCIDIA CARYOBORI*, HANNA (HYMENOPTERA, CHALCIDINAE).

By A. D. HANNA, B.Sc., A.R.C.S.

During my work on the life-history of the Chalcid, *Euchalcidia caryobori*, Hanna (Hanna 1933), which parasitises the pupae and the late larval stages of the Bruchid, *Caryoborus pallidus*, Oliv., infesting senna pods, great difficulty was experienced in obtaining the material. Infested senna pods arrive in London from the Sudan between June and August. Any pods arriving after or before that are not usually infested to any considerable extent. To guard against this lack of material, a large supply of parasitised and unparasitised pupae of the Bruchid was obtained when available by sifting the senna pods and keeping them in large glass jars at a constant temperature of 27°C. The Chalcid soon emerges and deposits its eggs through the cocoon on the unparasitised pupae of the Bruchid and feeds on peeled sultanas placed on a cardboard tray on top of the material and moistened every day. The sultanas were changed every three days to avoid fermentation.

The parasitised pupae of the Bruchid containing only the early stages of the pupae of the Chalcid were always picked out of the culture every two days. It is possible to see through the cocoons by placing them on a plate of glass standing over a strong light. They were then placed in glass tubes in the laboratory with a temperature ranging roughly from 15 to 23°C. This low temperature was enough to retard the growth of the pupae for a considerable time. If, on the other hand, the imago of the Chalcid was required at any time, some of these pupae could be transferred to a constant temperature of 27°C., at which they soon emerge.

For the purpose of working out the number of eggs laid by each female and the difference in the length of the life-history of the male and female, 53 pairs were obtained by transferring some of the above-mentioned parasitised Bruchid pupae from the laboratory, where they had been kept for 15 days, to a constant temperature of 27°C. After emergence each pair was placed in a glass tube with a piece of moistened sultana and five pupae of the Bruchid, which were dissected daily and replaced by fresh material. The eggs obtained were reared exposed on the host in block watch-glasses to observe their development. Out of 53 pairs 39 lived for the normal period. The rest died without laying the full complement of eggs, probably because of their antennae being cut off or because they became sticky with syrup from the sultanas. The average number of eggs laid was 88, with a maximum of 181. Two individuals did not lay eggs at all. Altogether *132 males and 18 females were obtained, which shows an overwhelming preponderance of males. In ordinary circumstances (*i.e.*, continuously at 27°C.) the males and females are equal in numbers. This result was surprising and led me to suppose that there might be some factor at work resulting in one or more of the following: (1) The non-formation of sperm; (2) the failure of the sperm to reach the egg; (3) the failure of the fertilisation process itself. But whatever that factor was, it did not greatly affect the egg-laying capacity of the females, for the average number of eggs laid was very little below the normal average, which is 102.

To find out whether this biological defect lay in the males or in the females, 15 female pupae were kept in the laboratory for 15 days immediately after pupation, and after emergence each was placed with a male bred from egg to adult in a constant

* The smallness of the number reared is explained later (p. 317).

temperature of 27°C., and then the same procedure as in the above-mentioned experiment was followed. The number of females produced was 34, that of the males 39. It seems evident, therefore, that nothing hindered the fertilisation of the eggs. It was therefore thought that the males were defective in the first experiment, and this would account for the great preponderance of males over females in my breeding work, since unfertilised eggs always produce males.

It was thought desirable to investigate the factor which so acted on the males. At the outset it looked as if the inbreeding of the individuals in the culture for two or more generations, together with the artificial conditions under which they lived, was the chief factor. Testing the egg-laying capacity of normal females and the fertility of the males which were in the culture and had always been kept at a constant temperature of 27°C. was enough to establish or eliminate the importance of that factor. Thus 56 pairs, just emerging, were taken and the number of eggs laid by each female was recorded. The average number of eggs deposited was 98, which is the normal number of eggs laid, and the maximum 220. Four females did not lay any eggs. The number of males obtained was 136, and 143 females, thus showing that inbreeding was not the real cause.

It remained to study the possible effect of low temperature on the pupae. If they were kept in the laboratory for a longer time than 15 days, would it also affect the egg-laying capacity of the females? Furthermore, would it be possible to reach a point where the emerging females would not lay any eggs at all? For this purpose 37 females that had been kept in the laboratory as early pupae for 36 days were obtained and each placed in a tube with a male reared from egg to adult in a constant temperature of 27°C. The average number of eggs laid was 7, the maximum 32. Fourteen females did not lay eggs at all; 18 males and 10 females were obtained, and although there was a majority of males over females, yet the number was not large enough to draw any conclusion as to the defect of the males.

Again, 22 pupae were kept in the laboratory 50 days, 2 females only laid eggs, 1 and 37 respectively, and 20 females died before laying any eggs.

It is evident, therefore, that temperature was the main factor, acting first on the males and later on the females.

The above-mentioned preliminary experiments were carried out on the early pupae to define the factor, and then other experiments under more controlled temperature conditions were devised. This was obtained by an electric incubator; but although its temperature was fairly constant at 16°C., it occasionally gave a range from between 13° to 19°C.

In the following experiments the eggs and larval stages were reared exposed on the host in block watch-glasses at a constant temperature of 27°C., and the pupae were transferred to the incubator immediately after their metamorphosis from the larvae. They were divided into three groups, each being subjected to the low temperature of the incubator for a certain period, after which they were transferred to a constant temperature of 27°C. until emergence. Then each pair was kept in a separate glass tube with a piece of sultana and 5 pupae of the Bruchid, which were dissected and replaced every day. The glass tubes were always placed in a constant temperature of 27°C. in a large glass jar with an air-tight stopper to prevent the drying-up of the sultanas. The eggs obtained were reared exposed on the host in block watch-glasses.

In the *first group* 25 female and 25 male pupae were subjected to a temperature of about 16°C. for 10 days. The average number of eggs laid was 81, which is a little below the average normal of 102; the maximum 127. The eggs belonging to each female were kept in a separate watch-glass so that it would be possible to recognise which females had been fertilised. Altogether 122 males and 25 females were produced. The latter were obtained from 7 males, and if we take into account the 2 females

that did not lay any eggs, we can gather that 7 out of 23 females were successfully fertilised, or in other words about 70 per cent. of the males were sterile.

In the *second group* 22 female and 22 male pupae were kept at 16°C. for 25 days. Only 8 females laid eggs; the average number of eggs was 6, the maximum 54. Fourteen, or 63.5 per cent., of the females did not lay any eggs. Fifteen individuals were obtained from these eggs, all males.

Because the number of eggs laid by this group was very small, it was not possible to determine the fertility of the males in the same experiment, and thus it was thought desirable to test the fertility of the males with females that had been bred throughout in a constant temperature of 27°C. Thus 20 male pupae were subjected to a temperature of about 16°C. for 25 days and, after emergence in a constant temperature of 27°C., each was kept with a female bred in the latter temperature. The eggs of each female were again kept separate. The number of individuals produced was 108 males and 7 females, the latter produced by two mothers. The sterile males were therefore 90 per cent.

In the *third group* 32 female pupae were subjected to the low temperature for a still longer time, 40 days. Three females only laid 3, 4, and 51 eggs, respectively, 29 (or about 90.5 per cent.) did not lay any eggs.

To test the fertility of the males of the latter group 20 of them were each placed with a female bred throughout in a constant temperature of 27°C.; 116 individuals were produced, all being males (sterility 100 per cent.).

It will be noticed that the number of individuals produced from these experiments was very small, as a great number of eggs failed to hatch because they were reared exposed; moreover, owing to the occurrence of superparasitism among the larvae, a great many of them were attacked by fellow larvae; if two or more happened to be on the same host, one larva only survived.

It may be argued that exposure (*i.e.*, rearing on host-pupae extracted from the cocoon) may have a differential effect on the eggs in such a way that it would affect the eggs destined to be females, and this may account for the preponderance of males over females. But in the two experiments mentioned above in which the fertility of the males was tested, the eggs were also exposed, and yet the number of males and females were equal.

Effect of Low Temperature on the Size of the Testes.

The testes of the males belonging to the third group (pupae kept cool for 40 days) were larger than those of normal males. This may have been due to the passage of the spermatozoa from the testes to the vesicula seminalis in the normal males, while the absence or reduction of spermatozoa in the third group may account for the large size of their testes.

Effect of Low Temperature on the Larvae.

Sixty last stage larvae were exposed to the low temperature of the incubator for 55 days; 5 of them metamorphosed into pupae and the rest were in such a dormant state that it was very difficult to know whether they were dead or alive. Then they were placed separately in a constant temperature of 27°C. After emergence, each couple was kept in a glass tube with pupae of the host and fed as in the previous experiments. The average number of eggs laid was 90, which is very little below the normal average. The number of males produced was 69 and that of the females 62; therefore the fertility of the adults was not affected when their larvae were subjected to the low temperature for a very long time, and it seems likely that under natural conditions the species passes the winter as a larva. This possibility is supported by the fact that some live larvae were collected from London docks

in February after passing the English winter, while all the pupae and the adults were dead.

According to Dr. Hurst, the chief meteorologist of Egypt, the average temperature during the winter in the region of Port Sudan, from which the senna was shipped, is 22°C., and it seems that the insect escapes the effect of that low temperature by hibernating as a larva.

Effect of Low Temperature on the Coloration of the Adult.

It was noticed that the colour of the adult becomes darker under the influence of low temperature. The antennae, tarsi, and tegulae, especially of the female, which are very pale brown in normal specimens, becomes almost black. This change of colour has been noticed by many authors in different families of Hymenoptera.

Effect of Low Temperature on the Reproductive Organs.

The Female.

The microscopic examination of the ovaries of females of different ages belonging to the second and third groups (fig. 1), as compared with the newly emerged normal ones (fig. 2), shows that low temperature has a differential effect on the ovarioles. In its extreme effect we find the six ovarioles shrunk into very short tubules; in this case the female would be completely sterile. Some have one or more ovarioles on one or both sides shrunk or degenerate, while the rest contain small nutritive chambers alternating with very small immature eggs. In some cases this condition was found even in females 47 days old, the average longevity of the normal female

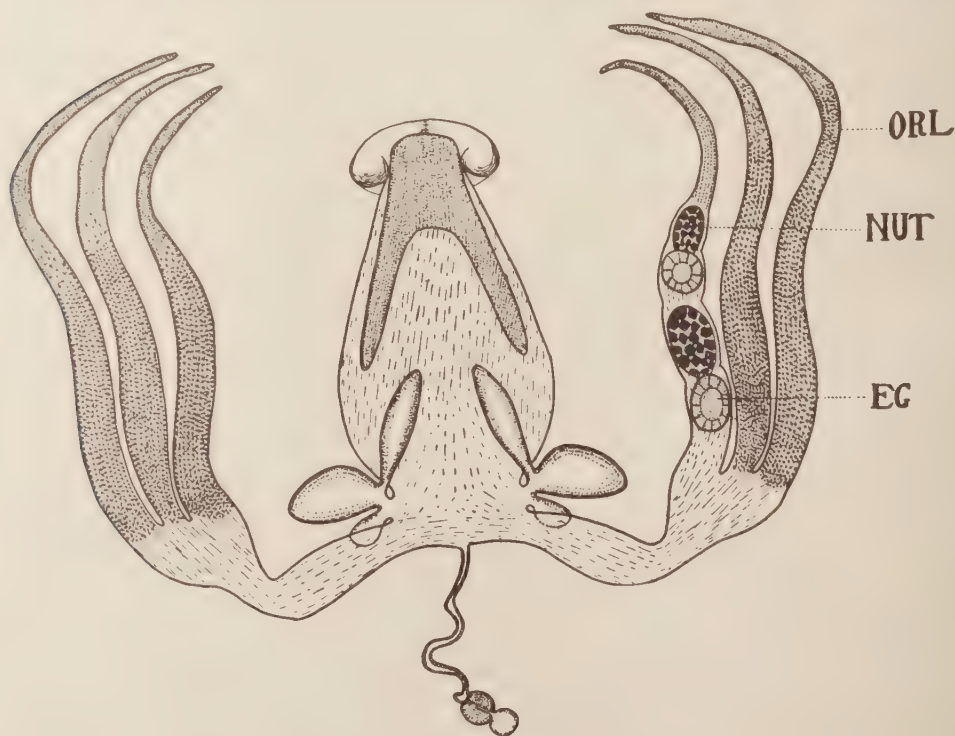


Fig. 1. A sterile ovary: *eg*, egg chamber; *nut*, nutritive chamber; *orl*, ovariole.

being 51 days. In some preparations, especially of young females, we find the ovarioles consisting of long slender tubules similar to those of the pupae without any differentiation into egg- and nutritive-chambers, and it seems probable that these females, had they lived, would have laid eggs later. On the other hand, some ovarioles were found to contain mature eggs but not so many as the normal ones. Females having such ovarioles would lay an egg or two occasionally.

From this, it seems that low temperature continued over a long time may cause either the retardation of the growth of the eggs, or, in its extreme effect, the malformation of one or more ovarioles.

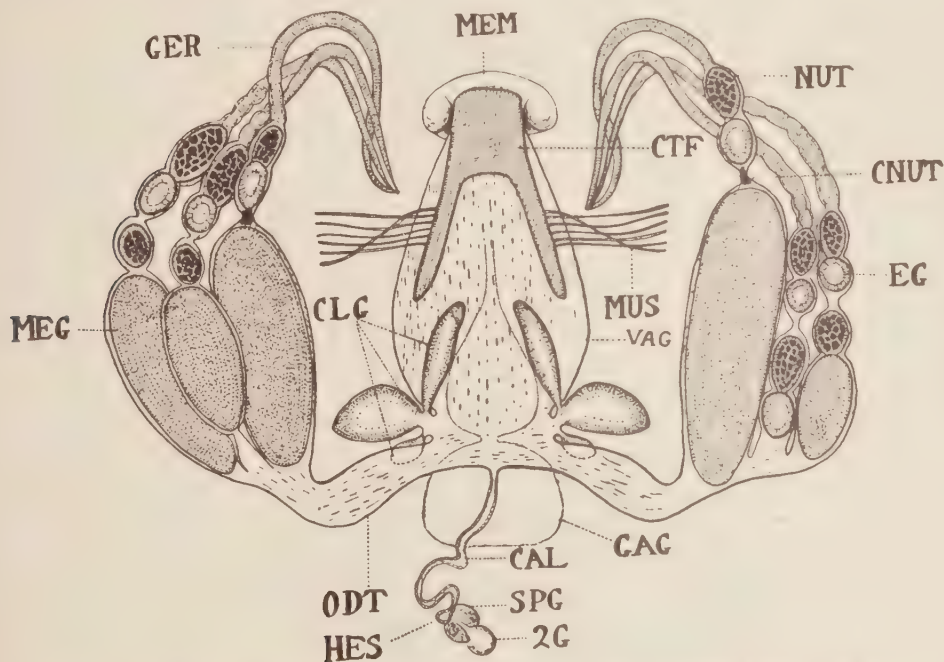


Fig. 2. Ovary of a newly emerged female: *cal*, canal; *clg*, colleterial glands; *eg*, egg; *gag*, 2nd abdominal ganglion; *cnut*, collapsing nutritive chamber; *ctf*, chitinous fork; *2g*, 2nd gland of spermatheca; *ger*, germarium; *hes*, head of spermatheca; *meg*, mature egg; *mem*, membrane; *mus*, muscles; *nut*, nutritive chamber; *odt*, oviduct; *spg*, spermatheca; *vag*, vagina.

The Male.

From the microscopic study of the vesiculæ seminales, it seems very difficult to draw a sharp line between sterile and fertile individuals by the criterion of the presence or absence of the sperm, especially in the first and second groups.

It is remarkable that some males had in their vesiculæ seminales what appeared to be scattered spermatozoa and yet failed to fertilise females, though some of them were seen to copulate. It may be noted that copulation cannot be seen very frequently, as the females do not copulate more than once.

The vesiculæ seminales of the males belonging to the third group were examined in males from 1 to 10 days old, but seemed to be empty.

Five testes of each of the three groups and also five testes of males reared at a constant temperature of 27°C. were cut in paraffin, transversely, with a thickness of 5 μ , and stained in Heidenhain's iron haematoxylin. All males used were 2 days

old and the sections chosen for examination were as near the middle region as possible.

Testes of the males reared at 27°C. contained a great number of spermatozoa (fig. 3), some specimens being full of them, while the premetamorphic cells (which do not exhibit any trace of metamorphosing sperm) were very few, sometimes absent.

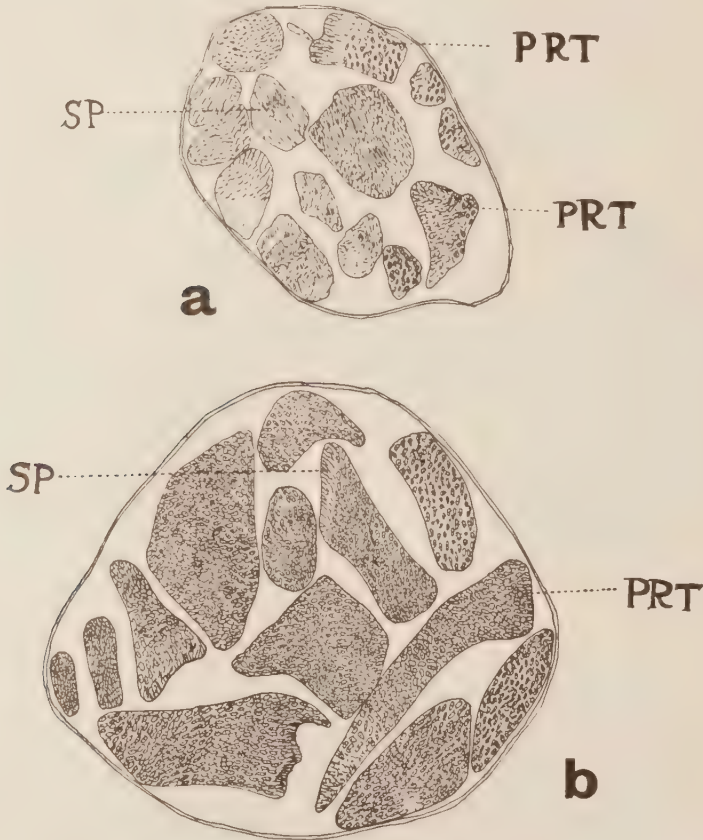


Fig. 3. *a*, transverse section of a testis of a normal male (2 days old); *b*, transverse section of a testis of an adult male of the third group, two days old (pupa kept 40 days at 16°C.) *prt*, premetamorphic cells; *sp*, sperm.

The spermatozoa in the testes of the first group were fewer than in the normal group, while premetamorphic cells were present, but not frequent.

In the second group, the spermatozoa were few, but the premetamorphic cells were abundant.

The spermatozoa in the third group were very few indeed, sometimes absent, and the testes were almost full of premetamorphic cells (fig. 3, *prt*).

In the second and the third group distinct signs of degeneration were shown by the premetamorphic cells.

From this it will be gathered, that low temperature causes, at least, the retardation of spermatogenesis. In its extreme effect it may cause the degeneration of the premetamorphic cells.

Discussion.

Exact experimental data on the influence of low temperature on the fertility of insects are not very extensive.

Sikora (1915) found that the louse, *Pediculus vestimenti*, L., did not lay any eggs at a temperature lower than 25°C. Pospelov's work (1916, 1926) on the maturation of the gonads of *Locusta migratoria*, L., shows that they mature within a month at a temperature of 35°-38°C., while individuals kept at a temperature of 20°-30°C. do not lay any eggs. Voelkel (1924) kept the males of the beetle, *Trogoderma granarium*, Everts, at a temperature from -8° to -10°C. for 3-4 hours and found that it did not affect their fertility. Males kept at -8°C. for 30 hours were sterile. Mayne (1926) showed that the mosquito, *Anopheles quadrimaculatus*, Say, does not lay any eggs between 4.4° to 12.2°C.

The result of the experiments described in this work shows that the tissues of the testes are more sensitive to low temperatures than the tissues of the ovaries; for, after exposing the pupae of both the male and the female to a low temperature (16°C.) for 10 days, the females still laid the normal number of eggs, while 70 per cent. of the males were sterile. These results seem to agree with those obtained by Norris (1933) in her work on the sterility of *Ephestia kühniella*, Z., at high temperatures. She found that the sterility was due to some abnormality on the part of the males only.

Young & Plough reared *Drosophila* at a temperature of 32°C. and found that 96 per cent. of the males were sterile, but only 50 per cent. of the females.

Raichoudhury's work on the retardation of spermatogenesis in *Ephestia kühniella*, Z. (in press), at high temperatures (27° and 30°C.), and Young & Plough's on *Drosophila* (also at high temperatures), show that the testes of sterile individuals contain some scattered spermatozoa, which is also the case in the testes of my sterile groups. It appears that those spermatozoa which are produced must be in some way abnormal, but this question has not been investigated.

Acknowledgments.

My thanks are due to Professor J. W. Munro under whose direction this work was carried out. I am also very much indebted to Mr. O. W. Richards, Mrs. O. W. Richards, Mr. H. R. Hewer and Dr. D. P. Raichoudhury, for valuable advice and help.

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NEW RECORDS AND THREE NEW SPECIES OF AMERICAN *DIATRAEA* (LEP.: PYRAL.).

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(PLATE XII.)

Since the publication of my 1931 revision¹ of the genus *Diatraea*, Guelding, in which 48 American species were treated, a considerable number of additional specimens of these moths has reached me from various sources. This material forms the foundation of the present paper, but I am also taking advantage of this opportunity to add certain references to the systematics which have come to my notice recently, as well as new locality and host records and descriptions of the early stages of some of the species; the larval and pupal descriptions, however, are given primarily for the use of field workers, and should not be interpreted as technical diagnoses.

For the majority of the 344 specimens now examined,* and for all three new species, I am greatly indebted to my friend Dr. J. G. Myers, who reared them from known food-plants during his several recent (1931-1935) explorations in tropical South America and the West Indies. Elsewhere^{2, 3} Dr. Myers has published accounts of the localities and food-plants (all Gramineae) in which the larval stages were found, and his latest contribution³ presents valuable ecological notes on 11 species, 9 of which have been traced by him to their original primitive habitat. Bred adult moths which Dr. Myers has sent to me represent almost all of the localities and hosts noted by him, but a certain number of the latter, from which adults were not reared, have been placed on record in Dr. Myers' own publications. I am including in the present paper, however, a few authentic and hitherto unpublished food-plant records of my own, likewise not supported by specimens, in order to bring these up to date.†

To Professor H. A. Ballou, C.B.E., and Mr. F. W. Urich, of the entomological staff of the Imperial College of Tropical Agriculture, I am much obliged for permitting me to examine and report upon all *Diatraea* specimens in their collections, and to Mr. T. Vogliotti, entomologist of the Haciendas Redo & Cia., Eldorado, Sinaloa, Mexico, I wish to record my thanks for sending me reared adults as well as early stages of *D. considerata*, Heinrich, a species described since my own paper in 1931.

The order in which the described species are arranged is for convenience the same as that adopted in my previous paper, where full references to the original descriptions and synonymy are given; it will be understood therefore that synonymic references in the present paper are additions or (in the case of *Phalaena saccharalis*) corrections to those already listed by me.

Types of the new species are in the British Museum and paratypes as well as representative series of the other species have been presented to that Institution as well as to the United States National Museum, Washington.

* It has been my custom, since the commencement of my systematic studies on *Diatraea*, to give a serial number to each specimen passing through my hands, a complete record of which I keep in a register; the serial numbers also appear on my identification labels attached to the specimens. The 1931 paper was based on Nos. 1 to 1290 and the present paper on Nos. 1291 to 1635.—H.E.B.

† A complete list of "The Food-plants of American *Diatraea* species," by the present writer has recently been issued as a Memoir by the Imperial College of Tropical Agriculture, Trinidad.

As on previous occasions I have to thank Mr. W. H. T. Tams, of the British Museum, for checking my descriptions and for being good enough to make photographs of the genitalia of the species here described as new, reproduced on the accompanying plate.

Genus *Diatraea*, Guelding.

Diatraea minimifacta, Dyar.

Diatraea minimifacta (Dyar), Box, Bull. Ent. Res., xxii, 1931, p. 21, pl. v, fig. 5(?).

Mr. F. W. Urich has been good enough to show me his MS records of this species, determined by the late Dr. H. G. Dyar, reared from larvae in sugar-cane, Caroni Estate, Trinidad, B.W.I., in 1912.

Diatraea saccharalis, Fabricius.

Phalaena saccharalis, Fabr., Skrift. af Naturhist.-Selsk., iii (2), 1794, p. 64, pl. vii, fig. 1; Ent. Syst., iii (2), 1794, p. 238. *Phalaena (Pyrallis) saccharalis* (Fabr.), Turton, Gen. Syst. Ent., i, 1806, p. 283.

Diatraea saccharalis (Fabr.), Comstock, U.S. Dept. Agr. Entom. Rept. 1880, 1881, p. 240 (*nec D. saccharalis* (?) Fabr., Comstock, *l.c.* p. 243 = *D. crambidoides*, Grt.); von Hedemann, Ent. Zeit., Stett., 55 Jahrg. 1894, p. 298; Ragonot, Ann. Soc. Ent. Fr., lxiv, 1895, p. ccxxi; Kaye, Trans. Ent. Soc. Lond., 1901, p. 151; Fauna Trinidad, i, pt. 3, 1914, p. 128; Kaye & Lamont, Mem. Dept. Agr. Trinidad & Tobago, No. 3, 1927, p. 128; Box, Bull. Ent. Res., xxii, 1931, p. 22, pl. iii, fig. 8.

It will be noticed that I have reversed the order in which Fabricius' two 1794 publications were cited in my 1931 paper, and that I now refer the original description to the *Skrifter af Naturhistorie-Selskabet*, following von Hedemann (*op. cit.* p. 299), who states "Nun gab aber Fabricius seine erste Beschreibung des Thieres nicht in der Ent. Syst., sondern in der oben citierten 'Skrift. af Naturhist. Selsk.' wo die Diagnose lautet: *Alae interdum fere immaculatae*. Das 'fere' wird aus Versehen in der späteren Beschreibung in der Ent. Syst. weggelassen worden sein." von Hedemann shows that the presence or absence of the word "fere" (almost) in the description has an important bearing on the determination of the series of moths "partly bred and partly captured" (trans.) by him in St. Croix.

Through Mr. Tams' kind aid at the British Museum I have been fortunate in having access to a copy of the *Skrifter* and on pp. 63-64 of Fabricius' article ("Beskrivelse over den skadlige sukker og bomuldsorm i Vest Indien. . . .") (Description of the injurious Sugar- and Cotton-worms in the West Indies. . . .) it is stated: "The first or sugar caterpillar has, so far as I know, never yet been described or figured. Englishmen in the West Indies call it 'the Borer' (*sic*) and it is capable of reducing a sugar crop of 300 barrels to 20-30 barrels. The larva develops into a small moth, known according to the classification of Linnaeus as a *Pyrallide*."*

Then follow the name *Phalaena saccharalis*, the diagnosis in Latin (nearly verbatim that in the Ent. Syst.), and some observations on the life-history supplied by Fabricius' "worthy friend and promoter in science Lieut.-Colonel von Rohr." The figures of the larva, pupa and adult moth, accompanying the article, were made

* For this translation from the old Danish I am much obliged to Miss Smyth, of the Imperial Institute of Entomology, and for the translation of von Hedemann's article to my good friend Mr. L. Nell.—H.E.B.

by von Rohr's friend Captain Mühlenfels. In the Ent. Syst. there is no reference to the first description published in the Skrifter, but the names of both von Rohr and Mühlenfels are mentioned. Four years later, when Fabricius changed the name to *Crambus sacchari* (Suppl. Ent. Syst., 1798, p. 469) he cited both of his previous (1794) references to *Phalaena saccharalis*, placing that in the Ent. Syst. first, and in this he has been followed by all subsequent authors with the single exception of von Hedemann, to whom special credit is due for his careful and thorough investigation of the subject.

In my 1931 paper I stated, when discussing *D. saccharalis*, that no type is known to us. Von Hedemann states that he compared Fabricius' description with his types, a fact which was also put on record the following year (1895) by É. L. Ragonot: "M. le baron von Hedemann . . . a comparé ses spécimens avec les types originaux de Fabricius, qui existent encore au Musée de Copenhague."

Examination of further specimens of *saccharalis*, chiefly from St. Lucia and other British West Indian islands, in which the frontal protuberance is very pronounced and sometimes even pointed (cf. *D. saccharalis grenadensis* (Dyar) and *D. s. oblitteratellus* (Zeller), Dyar, Ent. News, xxii, 1911, p. 200) renders certain modifications necessary in the "Key to the Species" on pp. 12-17 of my 1931 paper. Males of this form would run to couplet 32: 14. *guatemalaella*, Schs., from which they differ by not having a distinct elongate fuscous patch below the cell, forming part of the pattern of the fore-wing. Females would run to couplet 37: 13. *pedibarbata*, Dyar; 12. *tabernella*, Dyar, from which species *saccharalis* can be separated with certainty only by a study of the genitalia. The male *saccharalis* differs from the last-mentioned two species in the absence of a large brown hair-tuft on the hind tibia, as well as in the genitalia.

80 ♂♂ and 100 ♀♀ have been examined in the course of the present studies:— U.S.A.: Audubon Park, Louisiana, 17.vii, 16 & 23.ix.1914, "at light" (U. C. Loftin). JAMAICA: in sugar-cane, 1934 (W. Edwards). HAITI: Etang Miragoâne, larva in *Luziola spruceana*, 13.viii.1931 (Myers). ANTIGUA: "In cotton fields," in Indian Corn, 17.iii.1908 (H. A. Ballou); larva in sugar-cane and maize, 1931-34 (H. E. Box). ST. LUCIA: in maize, iv.1931 (Myers); in sugar-cane, maize, *Hymenachne amplexicaulis*, *Echinochloa polystachya* and *Panicum barbinode*, vii-x.1934 (Box). ST. VINCENT: Agric. School, in Guinea Corn, 30.x.1912 (Ballou); in maize and "at light," xi.1934 (Myers). TRINIDAD: (P. L. Guppy); in sugar-cane (F. W. Ulrich); Woodford Lodge, in sugar-cane, emerged 19.v.1910 (Ulrich); Chaguanas, in sugar-cane, 2.vi.1910 (Ulrich); Knaggs Hill, "at light," 19.xi.1921 (R. O. Williams); 4.ii.1929 (Myers); in sugar-cane, 29.i.1929 (Myers); Plum Road, Mitin, in *Panicum grande* (D. Vesey-Fitzgerald). VENEZUELA: Puerto Caribe, nr. La Guayra, 6.i.1932 (Myers); Ocumare de la Costa, in *Panicum grande*, 16.xii.1930 (Myers); Amakura, in *Hymenachne auriculata* (Myers); Puesta Morada, Lower Orinoco, and El Toro, Orinoco Delta, in *Paspalum fasciculatum*, i-ii.1935 (Myers). BRITISH GUIANA: Yarikita, in *Paspalum repens*, iii.1931 (Myers); Apoteri, Rupununi River, "at light," 18-21.vi.1933 (Myers). BRAZIL (LOWER AMAZONS): Pará, Igarapé-Mirim, in sugar-cane, 9.vii.1932 (Myers); Fordlandia, Boa Vista do Rio Tapajoz, in *Paspalum repens*, 27.vii.1932 (Myers); Santarem, in *P. repens* and *Echinochloa polystachya*, vii.1932 (Myers); Alemquer, in *P. repens*, 2.viii.1932 (Myers); Mouth of Rio Branco, in *P. virgatum*, vii.1933 (Myers); Janauacá, nr. Manaus, "at light," 29.vii.1933, Rio Solimões, in *P. repens*, viii.1933 (L. C. Scaramuzza); in undetermined water-grass, xi.1933 (Myers); nr. Obidos, in *Paspalum fasciculatum*, 15.xi.1933 (Myers); Paraná do Valle, Furo de Ramos, in *P. fasciculatum*, *Hymenachne* sp.?, *E. polystachya*, *Leptochloa panicoides* and "at light," 16-19.xi.1933 (Myers); Itacoatiara, in *P. fasciculatum* and *L. panicoides*, 20.xi.1933 (Myers); nr. Paraná da Terra Nova, in *Echinochloa crus-garonis*, 21.xi.1933 (Myers).

Additional Records:—BAHAMA Is.*: Borings in sugar-cane, v.1932 (J. G. Myers). ST. KITTS: in *Coix lachryma-jobi* and *Trichachne (Valota) insularis* in sugar-cane areas, 1932–33 (H. E. Box). NEVIS: in sugar-cane, vi.1934 (Box). MONTserrat: in sugar-cane at 1,200 ft. alt. and in maize all localities, vii.1934 (Box). ANTIGUA: Parham New Work, in *Panicum hirsutum* in dry cane-field pond v.1934 (Box). DOMINICA: in sugar-cane, 11.iv.1931 (Myers & Box). ST. LUCIA: Mini, on the Murray Road, 6 m. E. of Soufrière, at c. 1,300 ft. alt., in *Paspalum saccharoides*, viii.1934 (Box); Roseau Estuary, in *Panicum laxum* on edge of water-grass association, x.1934 (Box). ST. VINCENT: nr. Kingstown, in sugar-cane and maize, 7.iv.1931 (Myers & Box); in *Vetiveria zizanioides* and *Eleusine indica*, xi.1934 (Myers). GRENADA: in sugar-cane, 7.iv.1931 (Myers & Box). TRINIDAD: in sugar-cane and maize (in company with *D. lineolata*) at several localities, and borings with larval remains in *Tripsacum* sp. at Chaguanas, iii–iv.1931 (Box).

Diatraea brunnescens, Box.

Diatraea brunnescens Box, Bull. Ent. Res., xxii, 1931, p. 29, pl. v, fig. 1.

Diatraea incertella, Box, l.c., p. 30, pl. 1, figs. 16, 17.

2 ♂♂, 1 ♀. BRITISH GUIANA: Shiriri Mt., Rupununi, reared from larvae in the forest grass *Setaria vulpiseta*, 12–13.xiii.1933 (Myers).

A singularly fortunate discovery by Dr. Myers, in that it definitely establishes the identity of the unique male from Rio de Janeiro which (with some doubt, however) I described in 1931 as a new species, under the name *incertella*. The male and female genitalia of Myers' bred series agree exactly with those figured for *incertella* and *brunnescens*, respectively, in my 1931 paper.

The larva resembles that of *bellifactella* in size and general aspect. A spotted specimen (active feeding form) before me has the head and prothoracic plate very dark castaneous, and the well-defined body markings contrasting more sharply against the clear creamy-white body than is the case with *bellifactella*. Unspotted (aestivating) larvae are uniformly creamy-white in colour, with the head (except an area around the mouth-parts and ocelli, which is dark brownish) and prothoracic plate very pale yellowish; they resemble miniature larvae of *lineolata*.

Three pupa-cases are superficially indistinguishable from those of *bellifactella* except for their smaller average size (11–12 mm. in length).

Diatraea bellifactella, Dyar.

Diatraea bellifactella (Dyar), Box, Bull. Ent. Res., xxii, 1931, p. 31.

5 ♂♂, 3 ♀♀. TRINIDAD: Santa Estella, "at light," 14.ix.1912 (F. W. Urich); Verdant Vale, "at light," 20.xi.1913; Maquaripe and Sangre Grande, reared from larvae in *Setaria sulcata* in cacao plantations, iv.1931 (H. E. Box). I have found the species in similar habitat at the following additional localities in Trinidad: Maraval, Maracas Valley to c. 1,000 ft. elevation, Oropuche, Matura, Couva, Caura, and near Morne Bleu at 1,500 ft. (iv.1931 and x.1934). Dr. Myers records² finding this species under primitive conditions, in *Setaria sulcata* (its only known food-plant) in virgin forest near the south coast of Trinidad, between Guayaguayare and Moruga.

Considering the size of the moth, the larva of *bellifactella* is unexpectedly small, mature specimens seldom reaching 22 mm. in length, and averaging 18–19 mm.

*I have not actually seen an example of *saccharalis* from the Bahamas, but it may safely be inferred that the species occurs there, in sugar-cane, on the evidence of Myers, above, as well as a statement by L. G. Howard (Ins. Life, iv, 1891, p. 96): . . . in the spring of 1878 Mr. E. A. Schwarz sent in a bit of cane containing larvae from the Bahamas." The only other species known from this group of islands is *lineolata*, but this species attacks maize (*Zea mays*) and is unknown in sugar-cane.—H.E.B.

The head and prothoracic plate vary from pale yellowish to light castaneous, the head with a pronounced dark area surrounding the mouth-parts and the ocelli; the general body-colour is dirty whitish, sometimes almost grey, and frequently with a distinct lavender tinge laterally; spotted specimens have *light-brown* chitinated areas (tubercles) surrounding the principal thoracic and abdominal setae, forming the characteristic *Diatraea* pattern; in these specimens the posterior mesothoracic plate is four times as broad as long, with the posterior margin straight, and the anterior margin arcuate with a broad medium sinuation.

The pupa is from 12–19 mm. in length, castaneous; the posterior abdominal spining is rather weak, especially on the terminal segment.

***Diatraea albicrinella*, Box.**

Diatraea albicrinella, Box, Bull. Ent. Res., xxii, 1931, p. 34, pl. i, figs. 5, 6; pl. v, fig. 15; Trop. Agric. (Trinidad), xii, p. 221, 1935.

4 ♂♂. BRAZIL (LOWER AMAZONS): Paraná da Eva, reared from larvae in sugar-cane, in company with "an odd example of *saccharalis*," 21.xi.1933 (J. G. Myers). 2 ♀♀. TRINIDAD: Plum Road, Mitán, in *Panicum grande*, 10.i.1935 (D. Vesey-Fitzgerald).

Additional Records:—TRINIDAD: Guatcare River, Nariva Swamp, in *Panicum grande*, 13.x.1934 (H. E. Box); Guayaguayare, 3.i.1935 (Myers and Fitzgerald). Mr. Alan Pickles has recently communicated the extremely interesting record of this species boring in *Typha angustifolia* at Caroni.

The article in "Tropical Agriculture," cited above, gives all the Trinidad records of *albicrinella* to April 1935, including an account of its discovery by the present writer in its primitive habitat, as well as descriptive notes on the larva, pupa and adult.

***Diatraea canella*, Hampson.**

Diatraea sacchari (Sepp), Kaye & Lamont, Mem. Dept. Agric. Trinidad & Tobago, No. 3, 1927, p. 129.

Diatraea canella (Hmps.), Kaye, Trans. Ent. Soc. Lond., 1901, p. 151: Fauna Trinidad, i, pt. 3, 1914, p. 129; Box, Bull. Ent. Res., xxii, 1931, p. 35, pl. v, fig. 7.

24 ♂♂, 31 ♀♀. ST. LUCIA: in sugar-cane and *Paspalum virgatum*, vii–x.1934 (H. E. Box). ST. VINCENT: near Kingstown, in sugar-cane, 7.iv.1931 (Myers & Box). TRINIDAD: Caroni, bred, 19.x.1910 (F. W. Ulrich); Orange Grove, bred from pupa, 10.i.1912 (Ulrich); Balandra, 24.ix.1921 & iv.1923 (Ulrich); Penryth, 8.ix.1923 (H. A. Ballou); St. Augustine, 23.ii.1926 (Ballou); Filette, "at light," 1.x.1921 (Ulrich); Cedar Hill, iii.1931 (Ulrich); Rio Claro, in *Paspalum virgatum*, x.1930 (Myers). VENEZUELA: Carúpano, in sugar-cane, i.1931 (Myers). BRITISH GUIANA: Pariká, Rupununi, xii.1933–i.1934, in *Andropogon bicornis* (Myers).

Additional Records:—ST. VINCENT: in *Vetiveria zizanioides*, *Eleusine indica*, *Cymbopogon citratus* and sugar-cane, xi.1934 (Myers); GRENADA: in sugar-cane, 7.iv.1931 (Myers & Box). TRINIDAD: Caroni, in *Paspalum densum*, 24.iii.1931 (Box); Balandra Bay, in *Paspalum virgatum* and *P. millegrana*, 29.iii.1931 (Myers & Box); near Rio Claro, in *Panicum grande* by roadside, 2.iv.1931 (Box); Piarco and Mautica savannahs, in *Paspalum densum* and *Andropogon bicornis*, 15.x.1934 (Box, with Myers & A. Pickles).

Myers has traced the original habitat of *canella* in Trinidad to the littoral associations on the windward coast² and in British Guiana to the savannahs of the interior;³ more recently, Mr. A. Pickles has found the species inhabiting wild grasses on the edaphic savannahs in the interior of Trinidad, in which situations it was also seen by the writer.

The mature larva is large, often reaching 30 mm. in length and 4.5–5 mm. in breadth. The head, except for a small dark area enclosing the mouth-parts and ocellar region, and prothoracic plate uniformly yellowish or very light castaneous; posterior mesothoracic plate always a very pronounced triangle with the apex reaching at least as far anteriorly as a line joining setae I, and of the same colour as the body spots; body creamy white, often tinged with lavender around the lateral setae and their chitinous tubercles, the degree of chitination of these spots varying enormously; individuals may show the spots as hardly more than pin-pricks at the base of the setae, whilst others have the setae surrounded with sharply defined heavily chitinated (dark brown to almost black) areas in the same situations; in these examples the tubercles corresponding to abdominal setae I and II may measure as much as 0.8 mm. in diameter.

The pupa is large and stout, often reaching 22 mm. in length; light castaneous. Posterior abdominal spining generally very weak and frequently almost obsolete on terminal segment (an excellent character for separating *canella* pupae from those of *saccharalis*, *impersonatella* and *busckella*, the only other large sugar-cane species at present known within the range of *canella*).

***Diatraea amazonica*, Box.**

Diatraea amazonica, Box, Bull. Ent. Res., xxii, 1931, p. 36, pl. i, figs. 1, 2, pl. iv, figs. 4, 5.

5 ♂♂, 6 ♀♀. BRAZIL (LOWER AMAZONS): San Francisco, 5.viii.1932; Itacoatiara, 20.ix.1933; Santarem, 31.x.1933; Paraná do Valle, 16.xi.1933 (J. G. Myers); Santarem, ix.1933 (L. C. Scaramuzza); all reared from larvae in *Paspalum fasciculatum*.

The above series well illustrates the curious variation in the markings of the forewing noted in the original description, and furthermore shows that the large conspicuous blackish discocellular dot may be present in the male as well as in the female. Specimens in which the discocellular dot is of pin-prick dimensions are very similar to *canella* Hmps. (unknown from the Amazons region, however), but differ, having a dark apical shade in the forewing.

A mature larva before me (distended, in alcohol) would measure about 29–30 mm. in life; it is remarkably like that of *canella*, except that the head and prothoracic plate are dark castaneous, almost mahogany, instead of yellowish; the body segments are without any lavender tinge, and the large blackish chitinous spots contrast very sharply against the creamy-white ground-colour. Immature specimens show these spots almost coalescent along the whole length of the body dorsally and laterally.

Myers states³ that some larvae of *amazonica* are reminiscent of *busckella*, but these may possibly be *myersi*, sp. nov., found in the *amazonica* habitat and, according to Myers, also with a larva like small *busckella*. On the other hand they may be a normal variation of *amazonica*, in which case it would be most interesting to determine if this variation is correlated in any way with that of the adults.

The pupa is similar to that of *canella*, and totally different from that of *myersi* (q.v.).

***Diatraea cayennella*, Dyar & Heinrich.**

Diatraea cayennella, error for *cayennella* (Dyar & Heinr.), Box, Bull. Ent. Res., xxii, 1931, pl. v, figs. 10, 11.

1 ♀. BRITISH GUIANA: Rupununi savannahs, on edge of aete-palm grove, reared from larva in *Andropogon bicornis*, in association with *D. canella*, xii.1933 (J. G. Myers).

Dr. Myers' bred specimen is in a perfect state of preservation; it shows the barest traces of faint dotted cross lines on the forewing and without examination of the genitalia would be indistinguishable from *strigipennella*, Dyar (Castro, Paraná, Brazil), and probably also from *anathericola*, Dyar & Heinr., which has also been bred from *A. bicornis* in British Guiana (De Kinderen Plantation—H. W. B. Moore).

The larva, according to Myers, is quite unlike any other *Diatraea* with which he is familiar; he gives descriptive notes.³

I have one pupa-case before me, 12 mm. in length; it is rather thin and fragile, and differs from other *Diatraea* known to me in having the terminal abdominal segments very truncate; the spines are small and sharp.

Diatraea impersonatella, Walker.

Diatraea impersonatella (Wlk.), Box, Bull. Ent. Res., xxii, 1931, p. 41, pl. iii, figs. 2, 3.

18 ♂♂, 26 ♀♀. TRINIDAD: Union Hall, in sugar-cane, xii.1910 (F. W. Ulrich); Orange Grove, i.1912 (Ulrich); Cedar Hill, iii.1931 (Ulrich); Caroni, in *Paspalum fasciculatum*, i.1931 (J. G. Myers); various localities, in sugar-cane, *P. fasciculatum* and *P. virgatum*, 1929-34 (Myers). BRITISH GUIANA: Mt. Roraima, 4,400 ft., in *Axonopus scoparius*, xii.1932 (Myers); Kanaku Mts., in *P. virgatum*, i.1934 (Myers); Apoteri, Rupununi River, in *P. virgatum*, vi.1933 (Myers); Shiriri Mt., Rupununi, in *Paspalum milligrana*, *P. densum* and sugar-cane, 13-15.xii.1933 (Myers); Lama stop-off, "at light," 15.iii.1934 (Myers). BRAZIL, LOWER AMAZONS: Jararaca, in *P. virgatum*, 12.vii.1932 (Myers). A female, faded and rubbed, but whose genitalia agree with *impersonatella*, is labelled BRITISH GUIANA: Karabaku, Pakaraima Mts., Ireng River, in *Paspalum plicatulum*, 14.x.1932 (Myers).

Additional Records:—TRINIDAD: Caroni, in *P. fasciculatum*, 24.iii.1931 (Box); near Caroni, in *Panicum grande*, 30.iii.1931 (Box); Ste. Madeleine, in sugar-cane and *P. virgatum*, iii.1931 (Box); San Rafael, in *P. virgatum*, i.iv.1931 (Box).

Dr. Myers discusses³ the habitat of this important economic species. Whilst it has been traced to grasses in savannah associations it "might almost equally well be included among the riparian forms." It is rather curious that Myers failed to discover this species at or near Santarem, where he was stationed for a considerable time, for Walker described part (which I have not seen) of the type series from this locality.

The larva, which seldom exceeds 27 mm. in length, is similar to that of *canella* in the coloration of the head, prothoracic plate and abdominal markings; the meso- and meta-thoracic posterior plates, however, are distinctive, being in the form of a narrow transverse bar (as in *saccharalis*), this being an infallible character for the separation of larval *impersonatella* and *canella* in the field. With regard to the coloration of the abdomen Dr. Myers informs me that specimens may be found in which the lavender tinge at the sides is so well marked as to give the impression of lateral stripes.

The pupa is similar to that of *saccharalis*, except that the posterior abdominal spining is generally less pronounced, though always much more so than in *canella*.

Diatraea busckella, Dyar & Heinrich.

Diatraea busckella (Dyar & Heinr.), Box, Bull. Ent. Res., xxii, p. 43, pl. iii, fig. 5.

2 ♂♂, 2 ♀♀. COLOMBIA: Santa Marta, reared from larvae in sugar-cane, iv.1933 (J. G. Myers).

The above are yellowish, and agree with the original description based on specimens from Porto Bello, Panama, in that they do not exhibit the fine pinkish tinge

characteristic of all examples known from Venezuela, which form has recently been described as var. *rosa* (see below).

A series of larvae before me closely resembles *saccharalis*, and although I feel confident I could readily separate them in the field, it is difficult to indicate any reliable specific differences. The head and prothoracic plate vary in colour from reddish castaneous to dark mahogany; the posterior mesothoracic bar is long and narrow as in *saccharalis* and *impersonatella*; the abdomen has the rather small spots weakly contrasting against the uniform creamy-white ground colour.

The pupa is similar to that of *impersonatella*.

***Diatraea busckella* var. *rosa*, Heinrich.**

Diatraea busckella rosa, Heinrich, Proc. U.S. Nat. Mus., lxxix, 1931, no. 2879, p. 4.

1 ♂, 5 ♀♀. VENEZUELA: Puerto Caribe, nr. La Guayra; Caracas; Valencia; all reared from larvae in sugar-cane, xii.1930-i.1931 (J. G. Myers).

Venezuelan specimens listed in my 1931 paper under *busckella* are referable here.

The larva and pupa are the same as in typical *busckella*.

***Diatraea grandiosella*, Dyar.**

Diatraea grandiosella (Dyar), Box, Bull. Ent. Res., xxii, 1931, p. 44, pl. v, fig. 16; Davis & Horton *et al.* U.S. Dept. Agr. Tech. Bull. 388, Dec. 1933, p. 61, 28 figs., 14 tables, 13 refs.

The important American paper cited above contains a complete and well illustrated account of the history, distribution, bionomics, natural enemies and suggested methods of control of *D. grandiosella* (the "Southwestern Corn Borer") in the United States, as well as technical descriptions of the various stages by C. Heinrich.

***Diatraea lineolata*, Walker.**

Diatraea lineolata (Wlk.), Kaye, Mem. Dept. Agr. Trinidad & Tobago, No. 3, 1927, p. 128; Box, Bull. Ent. Res., xxii, 1931, p. 45, pl. iv, fig. 9.

Two published errors concerning this species require correction. In my 1931 paper it was stated that Van Dine's record of *D. lineolata* attacking sugar-cane in Cuba "is undoubtedly correct." Dr. Van Dine has written me fully on the subject, and in a letter dated 8th Jan. 1932 he says: "In the thousands of collections of *Diatraea saccharalis* we have made in sugar-cane in Cuba, we have not taken *D. lineolata*. I do not believe sugar-cane is a food plant of this species in Cuba, and I wish to correct the wrong impression I gave you in my statement in Bulletin 2" (*i.e.*, Trop. Plt. Res. Fndn. Bull. 2, 1926). The error arose from the earlier confusion of *lineolata* with *grandiosella*, which is known to attack sugar-cane within its range (Mexico & Southwestern U.S.A.).

The second correction is to my own statements^{4, 5} and that of Myers⁶ that *D. lineolata* has been found in maize in St. Lucia, B.W.I., which was based upon a mis-identification of an adult reared by Dr. Myers in 1931, and which later proved to be a female *saccharalis* with faded markings and a distinctly pointed frons.

3 ♂♂, 10 ♀♀. BAHAMA IS.: New Providence, in maize, 8.v.1932 (J. G. Myers). TRINIDAD: (P. L. Guppy); Princetown, "at light," 2.xi.1920 (D. Farrell); in maize, xii.1931 (Myers); St. Augustine, in *Euchlaena luxurians*, ii.1935 (D. Vesey-Fitzgerald).

The finding of this species in *Euchlaena* is especially interesting, as it constitutes the first authentic record of *lineolata* in any food-plant other than *Zea mays*.

The mature larva is large, up to 30 mm. in length; the head (except a dark area around mouth-parts and ocelli) and prothoracic plate are pale yellowish or very light castaneous, and the rest of the body uniformly creamy-white without any trace of spots. Spotted larvae occurring in *Zea mays* (the only known food-plant of *lineolata*) in South America and the West Indies, are almost certainly *saccharalis*, the only other *Diatraea* known to attack maize within this range.

I have only one pupa-case before me (from the Bahamas). The posterior abdominal spining is not so pronounced as in *saccharalis* and the upper surface of the terminal segment appears to be more rugose than is usual in the genus.

Diatraea considerata, Heinrich.

Diatraea considerata, Heinrich, Proc. U.S. Nat. Mus., lxxix, 1931, no. 2879, pl. 3, figs. 11, 12.

Stated by Heinrich to be "A large species allied to *D. magnifactella*, Dyar, the sexes showing marked contrast in color." The type material was reared from sugar-cane at Eldorado, Sinaloa, Mexico, by Dr. Stanley E. Flanders in 1929, and the species is evidently one of those discussed by him in J. Econ. Ent., xxiii, 1930, pp. 603-606.

I have seen three females and a long series of larvae, reared from sugar-cane at the type locality by Mr. T. Vogliotti in 1933.

The larva agrees with *impersonatella* except for the larger size (mature examples 32-33 mm. in length) and the very marked tendency for the dorsal and lateral spots to coalesce *transversely* across the middle of each segment. Curiously enough, small specimens (less than 16 mm. in length) are unspotted and with pronounced *lateral* stripes along the length of the body.

The large pupa (20-23 mm. in length) is very similar to that of *impersonatella*.

Diatraea myersi, sp. nov. (Pl. xii, figs. 1, 2).

♂. Palpus wood-brown below, light buff above. Antenna pectinate, shaft light buff. Head cartridge-buff tinged with light buff and warm buff. Thorax warm buff. Tergum light buff to warm buff, proximal two segments ochraceous tawny. Pectus cartridge-buff. Legs cartridge-buff to light buff. Forewing with general ground-colour light buff strongly tinged with warm buff near base of costa; the veins lightly contrasting in irrorated lines of scales darker than the ground-colour; a well-defined yellowish streak extending diagonally and gradually broadening from apex in a straight line, outside the cell, to inner margin at middle; a rather broad band of darker, almost fuscous, scales beyond the light streak extending to near outer margin; traces of a similar, but narrower, dark band on inner border of the yellowish streak; a fuscous blackish discocellular dot; another dot, somewhat larger but less sharply defined, between veins 1 c and 2 halfway between the discocellular dot and middle of inner margin; a terminal series of black dots. Hindwing cartridge-buff tinged with light buff, tinged with warm buff on costa; a terminal series of light brownish dots. Underside of both wings warm buff tinged with brownish towards costa. Expanse: 19 mm.

♀. Similar; larger. Antenna not pectinate. Forewing warm buff with surface much irrorated with darker (brownish) scales, the yellowish diagonal streak well contrasting; discocellular dot faint and the dot between veins 1 c and 2 almost obsolete. Hindwing whitish. Expanse: 20-21 mm.

The frons is smooth and rounded and very slightly protruding.

The male genitalia (tegumen, etc., unfortunately lost) with very long narrow pointed arms to the anellus; vinculum longer than broad; harpes with very slight smooth rounded projections near base. Female genitalia distinguished by the "double-funnel"-shaped chitinised neck to the bursa, and the very long narrow bursa.

Holotype ♂ and 4 paratype ♀♀.—BRAZIL, LOWER AMAZONS: Recreo, reared from larvae boring in stalks of *Paspalum fasciculatum* in riparian association, 3.viii.1932 (J. G. Myers); Santarem, "at light," 14.ix.1933 (L. C. Scaramuzza).

A small buff-coloured species readily distinguished by the yellowish streak which runs diagonally from the apex to the middle of the inner margin of the forewing, and by the characteristic genitalia.

Dr. Myers states that the larva resembles that of *busckella*.

The pupa is black (in this respect unique among *Diatraea* known to me), very rugose, and with the posterior abdominal spines long and thornlike.

***Diatraea savannarum*, sp. nov.** (Pl. xii, figs. 3, 4).

♂. Palpus avellaneous below, cartridge-buff above. Antennal shaft and head whitish tinged with cartridge-buff. Thorax whitish to cartridge-buff above, tinged with some avellaneous at sides. Tergum whitish to cartridge-buff, proximal two segments warm buff with a brassy sheen. Pectus, legs and venter whitish to cartridge-buff. Forewing with ground-colour whitish to cartridge-buff, the veins and inter-neural lines sharply contrasting in wood-brown and ochraceous tawny, respectively, this pattern very pronounced on the costal region and base of wing generally, but fading towards the outer margin, where the whitish ground-colour prevails; superimposed over this pattern are two oblique lines composed of elongate patches of wood-brown scales on and between the veins, the first (outer) in a gentle curve from apex of vein 7 to inner margin two-thirds its length from base; the second oblique line from an indistinct dark apical shade, passing just beyond the cell and thence in a curve to inner margin at middle; a narrow elongate pale streak through cell, within which is a fuscous blackish discocellular dot; a terminal series of rather large fuscous blackish dots, almost continuous with one another. Hindwing cartridge-buff or whitish, tinged with light buff on costa; a terminal series of light fuscous dots. Underside of forewing light wood-brown with terminal points and intercellular light streak well defined; of hindwing cartridge-buff tinged with some warm buff on costa. Expanse: 16–20 mm.

♀. Similar. Forewing with pattern less sharply pronounced; light streak through cell well defined but the two dark oblique lines rather obscure.

The frons is slightly projecting, with a sharp point at the apex.

The male genitalia have the harpes simple, without projection on the costa at base; anellus with a pair of smooth, flat, pointed arms of moderate length; vinculum broader than long; uncus beak-like; gnathos similar but spined on the inside for one-third its length from apex; aedoeagus with a well-defined cornutus. Female genitalia with the almost parallel-sided neck and the opening of the bursa lightly but distinctly chitinised; bursa rather long.

Holotype ♂, 3 paratype ♂♂, and 1 allotype ♀.—BRITISH GUIANA: Rupununi savannahs, at base of Shiriri Mt., reared from larvae boring in stalks of *Paspalum plicatulum*, 13.xii.1933 (J. G. Myers).

A small whitish species, with well-marked pattern in shades of dark brown, closely allied to *lentistrialis*, Hmps. (Argentina). The male genitalia resemble those of *venosalis*, Dyar, except for the presence of a cornutus in the aedoeagus.

According to Dr. Myers "the tiny larva resembles in markings those of *albicrinella* (see Myers³) but the pronotal bar is weak and indistinct."

The pupa-case, 9–11.5 mm. in length, is thin and fragile, with rather weak posterior abdominal spining.

***Diatraea maritima*, sp. nov.** (Pl. xii, figs. 5, 6).

♂. Palpus fuscous, irrorated with tilleal buff. Antennal shaft and head light buff mixed with fuscous. Thorax fuscous streaked with light buff. Tergum fuscous, the segments edged distally with light buff. Pectus and venter light buff. Legs light buff, fore and mid legs shaded with fuscous; posterior tibia with a large conspicuous tuft of hair-like scales on inner side, these scales *brownish* and strongly shaded with fuscous. Forewing with ground-colour fuscous to sepia irrorated with light buff, uniform except for a small indistinct triangular fuscous shade at apex; the veins barely contrasting; a fuscous black discocellular dot; two rather indistinct diagonal cross-lines formed of small dots, the first in a curve (concavity basad) outward from junction of veins 8 and 9 to near apex of vein 7 and thence inward and below the cell towards vein 2, just above inner angle; the second (inner) cross-line extends from near the apex of the cell in a uniform gentle curve around the discocellular dot to near base of vein 2, and thence almost straight to inner margin at about one-third its length from base of wing; a well-defined series of *blackish* terminal dots, that at the end of vein 2 prominent, irrorated with some fuscous scales apically; faint terminal series of fuscous dots. Underside of forewing fuscous, with a well-defined terminal line punctured with a series of terminal dots, the veins streaked with light buff; of hindwing light buff strongly tinged with *brownish* on costal margin. Expanse: 18–19 mm.

♀. Larger. Posterior tibia without tuft of hair-like scales. Forewing almost uniformly warm buff irrorated with warm sepia, with the pattern of the male almost entirely subordinated; discocellular dot distinct. Hindwing almost uniformly cartridge-buff, faintly tinged with warm sepia distally. Expanse: 23–24 mm.

The frons is smooth and rounded, barely projecting between the eyes.

The genitalia of both sexes are rather similar to those of *pedibarbata*, Dyar, though the female genitalia would seem to come closest to those of *suffusella*, Box.

BRITISH GUIANA: 3 ♂♂, 2 ♀♀, Plantation Ogle, 1930, "bred from *Spartina*, a sea-water rice grass that is common along our shores; I have also bred specimens from grass at Pln. Albion" (H. W. B. Moore); 2 ♂♂, 4 ♀♀, Georgetown, March 1935, reared from larvae.

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EXPLANATION OF PLATE XII.

- Fig. 1. *Diatraea myersi*, sp. n., ♂: harpes, vinculum and anellus.
.. 2. *Diatraea myersi*, sp. n., ♀: genital opening and bursa copulatrix.
.. 3. *Diatraea savannarum*, sp. n., ♂: *a*, harpes, vinculum and anellus; *b*, tegumen, uncus and gnathos.
.. 4. *Diatraea savannarum*, sp. n., ♀ genital opening and bursa copulatrix.
.. 5. *Diatraea maritima*, sp. n., ♂: harpes, vinculum and anellus.
.. 6. *Diatraea maritima*, sp. n., ♀: genital opening and bursa copulatrix.



GENITALIA OF *DIATRAEA* spp.

THE ECOLOGICAL DISTRIBUTION OF SOME SOUTH AMERICAN GRASS AND SUGAR-CANE BORERS (*DIATRAEA* SPP., LEP., PYRALIDAE).

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(PLATE XIII.)

1. Introduction.

In 1932 I published an account of the primitive habitat and original host-plants of a number of small moth-borers (*Diatraea* spp.) in the Greater and Lesser Antilles, in Trinidad, the coastlands of British and Dutch Guiana, the Orinoco Delta, northern Venezuela and the llanos to the Rio Apure (see list of references at the end of this paper). This survey has now been extended to the interior Guiana plateau, the Rio Branco, lower Rio Negro and lower Amazon, between Manáos and Pará. A more comprehensive account of the vegetation in this region will be found in several other papers (Myers, 1933, 1934) and in a description, now being prepared, of the grass-associations of the lower Amazon. Here only sufficient details are presented to explain the ecological distribution of the various *Diatraea* spp. I am deeply indebted to Mr. H. E. Box for determining so promptly my large collection of reared *Diatraea*, and to Dr. A. S. Hitchcock for naming my grasses.

The greatest immediate practical result of this survey was the discovery and introduction into British Guiana cane-lands of the Amazon fly parasite (*Metagonistylum minense*) of *Diatraea saccharalis*. This has been already described in "Tropical Agriculture" (Myers, 1934).

The most interesting ecological result was the finding, for the first time in the whole investigation, of several species of *Diatraea*, including the highly important economic species *impersonatella* and *canella*, as original members of a true savannah association. Mr. Pickles has since found the same two species in savannah in Trinidad. *D. canella* was previously known from coastal and swamp grass-communities and from wayside grasses in that island, and also, of course, from sugar-cane.

The fact that the Guianas and the Amazon are still virtually virgin country rendered them particularly favourable for the investigation of the original habitat of the borers. Apart from a narrow strip on the coast of British Guiana, there is no part where the area of cultivation, under whatever crop, is not surrounded and interpenetrated by a vastly greater expanse of primitive vegetation, whether forest—the dominant plant-community—or savannah or swamp.

In discussing the ecological distribution of froghoppers (*Tomaspis* spp.) allied to the sugar-cane species, I divided them into forest, riparian and savannah species, and showed that the only serious sugar-cane froghopper in our area was almost certainly a forest form originally. The species of *Diatraea* are amenable to the same classification, but whereas the sylvan froghoppers include several which are colonising man's clearings and roadsides and one which has invaded his cane-fields, leaving two which scarcely exist outside virgin rain-forest, the purely forest moth-borers, on the other hand, show less adaptability and the main sugar-cane pests seem to have been recruited from the riparian and savannah forms.

2. Forest Species.

Diatraea bellifactella, Dyar. This was considered a rare species, until Mr. H. E. Box paid a visit to Trinidad *en route* to his extensive *Diatraea* researches in the

Leeward Islands. During a discussion of its known range, I remarked that this seemed to include especially cocoa-growing countries, while the recorded localities in Trinidad were likewise in cocoa-districts. It occurred to me further that one very common grass, sufficiently stout to support *Diatraea* larvae, and not yet investigated as a possible host, was gamalote (*Setaria sulcata*), a widespread weed in cocoa-fields. That same day Mr. Box put the suggestion to the test and found this grass to be the hitherto unknown host-plant of *D. bellifactella*, at least in Trinidad. This is essentially a forest grass, and the ecological conditions of cocoa-fields under tall shade, as regularly supplied in Trinidad, are essentially those of rain-forest.

Diatraea brunnescens, Box (— *incertella*, Box, male). This borer was discovered in considerable numbers infesting the woodland grass, *Setaria vulpiseta*, at an elevation of about 1,300 feet on Shiriri Mountain, an isolated outlier of the Kanuku Mountains rising from the Rupununi Savannah country of British Guiana. Shiriri Mountain is very rocky, with dry *Trachypogon-Curatella* savannah extending well up the main slopes. The upper slopes are clothed with dryish, semi-deciduous scrubby forest, with such trees as *Cochlospermum* sp. and *Bursera simaruba*. At high levels there are moister valleys with rain-forest, in one of which wild plantains were found (Myers, 1934). The *Setaria* was growing luxuriantly at the lower edge of one of these rain-forest patches, where it merged into scrub and savannah. The majority of the larvae found were aestivating within the comparatively narrow bases of dry stems and they continued thus for six months afterwards, with still no sign of further development. These were whitish with a pale head. Spotted larvae, actively feeding in green shoots, were indistinguishable from those of *Diatraea bellifactella*, for which I mistook them.

3. Riparian Species.

Owing to the abundance of streams and the huge size of the rivers, riparian species are probably of greater importance in the region under review than elsewhere. Riparian grass-associations, as I have elsewhere pointed out, cover immense areas, both of land and water, in the Amazon system, especially on the yellow water rivers. Their *Diatraea* populations are so vast and so varied that it will be necessary for the purposes of this paper to describe these successive zones of semi-aquatic grasses in greater detail than in my previous contributions on the Amazon fly and on froghoppers.

In the neighbourhood of Pará and in the estuary, only small and infrequent floating or riparian grass-beds are encountered. About the Furo de Breves the first patches of water hyacinths (*Eichhornia* spp.) appear, and near Almeirim the first *Paspalum repens*. This, known locally as perimenbéca, in association, especially on the landward side, with large and stout *Echinochloa polystachya* (canarana) begins to form huge floating meadows and fringes, which reach their maximum development about Santarem, *i.e.*, about halfway between Santarem and Manáos. They are frequent, however, at suitable stations right up to Manáos and thence up the Solimões, but not extending into the Rio Negro, whose black water is not suitable for their development. They are frequently backed on drier land by a wide zone of morý (*Paspalum fasciculatum*). Three zones, then, form the essential feature of the riparian grass-beds on the yellow water rivers—a floating bed of *Paspalum repens*, a landward zone of *Echinochloa polystachya* in the water and on the mud, and higher up the bank a zone of *Paspalum fasciculatum*. There are modifications of this simple scheme. The perimenbéca may be mixed with or even replaced by canarana in the wide floating beds. The outermost fringe is, however, usually perimenbéca. Similarly the morý zone may be invaded for quite a distance inland, on to dry ground, by the canarana. Other grasses also occur, but rarely sufficient to modify a 95 to 98 per cent. dominance of these three grasses in their respective zones. Varying quantities of *Eichhornia*, *Azolla* and *Pistia* float among

the bases of the water-grasses. In the ecotone between canarana and morý isolated flattened plants of *Eragrostis maypurensis* are frequent.

At Fordlandia, on the Tapajoz (a clear water river), the same *Paspalum repens*, growing much less luxuriantly and backed by another grass, not yet determined, composes similar but local and far less extensive beds and fringes.

Both on the Amazon and on the Tapajoz, large areas of smooth mud exposed by the falling waters, whether on the river margins or in the beds of drying lagoons, become speedily covered with the fresh green shoots of *Luziola spruceana*, growing in pure stands for miles and aptly compared by Le Cointe to fields of young wheat. This is a host of *Diatraea saccharalis* in Haiti and elsewhere.

On the lower Rio Negro and along the Rio Branco, beds of aquatic grasses are almost absent, save for a few stretches of *Luziola* in sheltered bays, and the zone of morý is also less developed.

But the riparian grass-vegetation of the yellow water rivers, and especially of the stretch investigated on the main Amazon between Almeirim and Manáos, is much richer than the above sketch would indicate.

In the floating beds or on the mud, *Hymenachne amplexicaulis* and probably other species (some not obtainable in flower) of that genus are fairly frequent but local. At Santarem this grass is sometimes cut and carried into the town for fodder, as also is perimenbéca, but the chief grass—in overwhelming predominance—for this purpose is canarana. In the canarana zone, wild rice (*Oryza latifolia*) is a frequent constituent. *Panicum elephantipes* also occurs, but rarely.

For long stretches, especially from Obidos to Manáos, the silt exposed in front of the morý, the most stable of the grass zones, by the falling waters is covered by *Leptochloa panicoides*, either in pure communities or associated with *Eragrostis maypurensis*, occasional tall clumps of *Echinochloa crus-garonis* and scattered succulent shoots of *Jussieuia* sp. These *Leptochloa* stands, sometimes at the top of a low but clean-cut or under-cut cliff a foot or two high, at other times rising from a few inches of water, are obviously rather temporary communities. This leads us to remark that the above sketch represents only a static description of riparian grass-vegetation. The relative extent of the different zones varies tremendously with the regime of water-level, an ecological factor of outstanding importance on the Amazon. Beds of floating grasses are left high and dry by the falling water. The perimenbéca promptly withers away and the green spears of morý shoot through the matted carpet of dead stems and within a few weeks this grass is in complete possession. Canarana, on the other hand, resists well this desiccation and generally remains in possession of its zone, but the young shoots beloved of *Diatraea* are not replenished and the older stems, while still growing and rambling over the ground, become hard and woody, and conditions are not favourable for *Diatraea saccharalis*, its chief borer, until the returning water-level once more converts it into juicy aquatic grass. When high water comes, large masses of floating perimenbéca and canarana are wrenched off and float off as islands, sometimes of considerable size. The prairies of *Luziola*, at the same time, are completely disintegrated and the grass swept into the rivers.

The riparian grass communities of the Orinoco system, at least where we studied them at San Fernando de Apure, while also very extensive, present striking differences. The most extensive zone is that of the *Paspalum fasciculatum*, which springs up on the drying mud, as the water falls, and is frequently fronted by very few other grasses. Perhaps in association with a stronger current, the great floating beds of *Paspalum repens* do not occur, save in lagoons and backwaters. The dominant *P. fasciculatum* was infested by the borers, *D. saccharalis*, *D. canella* and *D. impersonatella*.

We may now consider the species associated with the Amazon grass-beds.

Diatraea saccharalis, Fabr. This is the riparian species *par excellence*. On the Apure it attacks the fresh green shoots of *Paspalum fasciculatum* as they sprout from the recently exposed mud, and abandon them to its more mesophytic congeners as the ground becomes hard and dry. On the lower Amazon its chief home, certainly covering many hundreds of square miles, is in the floating beds of *Paspalum repens*. In selected localities near Santarem I have seen the surface brown with "dead hearts" (killed shoots) caused by this species in pure culture, amounting practically to 100 per cent. infestation. This is the only *Diatraea* species reared from perimenbéca. It was only a little less frequent in canarana (*Echinochloa polystachya*), where, again, it was the only species reared. But it was by no means confined to these two aquatic zones. It occurred also, as a very small form in keeping with the thin stems of the host, in *Leptochloa panicoides*, where dead hearts were somehow very difficult to find. At a much higher rate of infestation we found it also in the scattered tall tufts of *Echinochloa crus-garonis*. Both these represent new host-plant records. Still another host was a stout, juicy *Hymenachne* sp. in the perimenbéca zone. As on the Apure, so also here, *Paspalum fasciculatum* is attacked, but not to the same extent as the above grasses. Moreover, nearly all the larvae cut out of morý seemed to be atypical, with the head appreciably paler than the pronotum. The same form of larva composed the borer population of a tall undetermined gregarious grass forming a well-defined zone behind the perimenbéca at Fordlandia on the Tapajoz. There the perimenbéca itself was very much less infested than on the Amazon—in fact borers were rare, but the larvae were all typical *saccharalis*. The *P. repens* at Janauaca, a little way up the Solimões, were, on the other hand, found by Mr. Scaramuzza to be heavily attacked by *D. saccharalis*. Near the mouth of the Rio Branco (a "white water" river), with practically no floating grass-beds, *D. saccharalis* was found in very small numbers in morý and *Paspalum virgatum* in a house clearing. In the latter host it occurred, with *D. impersonatella*, in riparian clearings of the Amazon estuarial forest.

On the whole of the lower Amazon *D. saccharalis* is rare in cane. We examined this question especially in the vicinity of Pará. A count made in Cana-branca near Igarapé-mirim showed a stalk infestation of 17 per cent., but in other cases it was much harder to find, even in mature cane, and practically absent from shoots. Wild rice, *Oryza latifolia*, growing among canes, was slightly infested.

In the Kanuku and Shiriri Mountains of the Rupununi savannahs and in the Pakaraima Mountains, all on the borders of British Guiana and Brazil, *D. saccharalis* was widespread but always rare as a borer in the sugar-cane of the small and scattered aboriginal Indian (Wapisiana, Macusi, Patamona, Serekong, Taulipang) provision-patches (always in forest, or in bush "islands" on the savannah—never on the open savannah). It was sometimes more frequent in maize.

Diatraea amazonica, Box. On the lower Amazon, especially between Santarem and Manáos, this is the regular species attacking morý, though never in any very great abundance. On the landward side, the morý zone is usually backed by forest, though itself it may be several miles wide. Where clearings have been made it is often fringed on the landward side by *Paspalum conjugatum* and (or) *Panicum laxum*. In the ecotone thus formed, where morý is only a straggler, *D. amazonica* sometimes follows it. The hitherto unknown larva is so much like that of *D. canella* that I almost invariably recorded it as such till it was finally reared and determined. Some specimens, however, are reminiscent of *D. busckella*.

Diatraea myersi, Box. This new species was discovered at light at Santarem and reared from *Paspalum fasciculatum* at a number of stations between Santarem and Manáos. The larva resembles that of *D. busckella*.

Diatraea albicrinella, Box. I include this species with some uncertainty among the riparian forms since I encountered it only once, and it is recorded from several other countries (British Guiana, Peru, Ecuador—Box) where it may live under

different conditions. I reared it from strikingly beautiful larvae boring in sugar-cane at a small farm on the Paraná da Eva, between Itacoatiara and Manáos. These larvae varied somewhat, but showed a pale head and pronotum with a nearly linear pronotal bar, no spots (or only in the lateral line), but a wide dorso-lateral stripe of lavender grey-brown down each side. These stripes in others were very dark—almost black. In their large size and in the nature of their burrow they resembled large *canella* caterpillars. The burrow consisted of a huge central cavity, causing quicker death than usual to the shoot. The sugar-cane, which was a white variety, very stout, tall and healthy, was grown within the cleared moré zone. The infestation was extraordinarily sporadic—most stools quite untouched, but one small stool, for example, with no fewer than 10 dead hearts—in fact all the young basal shoots being thus killed. *Metagonistylum*, the Amazon fly, was parasitising both this species and an odd example of *D. saccharalis* in the same cane-patch.

It seems probable that the original status of *Diatraea busckella*, Dyar & Heinrich, was also that of a riparian species. It is a regular inhabitant of the *Paspalum fasciculatum* zone on the Apure River.

4. Savannah Species.

In my earlier papers (1932, 1933), I considered the wide belt of *Paspalum fasciculatum* on the Apure River as a savannah community. In composition such it is, but it seems best, taking its genesis into consideration, to place it with the other riverine grass-associations in a separate category of riparian communities, forming savannahs of a seasonal and temporary nature.

Until the present survey, the more typical upland savannahs had yielded no borers of the genus *Diatraea*. We can now record four species of which this was probably the primitive habitat.

Diatraea canella, Hamps. This, the most important economic species, next to *D. saccharalis*, in British Guiana and the Windward Islands, was found in December 1933 by two of my trained Guiana assistants (H. Spence and C. Smith) in the Rupununi savannahs during our return from the Amazon. The lower areas, or baixas, of these savannahs, are often marked by the presence of aeta-palms (*Mauritia flexuosa*) in groves or long lines, often surrounding small lagoons or bordering creeks. Between the sedges of the actual water and the drier grasses of the open *Trachypogon*—*Curatella* savannah, occur the more mesophytic grasses, *Andropogon bicornis*, *Paspalum millegrana*, *P. plicatulum* (a very luxuriant form), *P. densum*, and *Panicum laxum*. They are often intermixed with numerous suffrutescent herbs. *D. canella* was found, with some difficulty, but eventually in considerable numbers, in the *Andropogon bicornis*. Larvae in old, dryish stems were white, and apparently aestivating; in green stems, heavily spotted. Associated in the same host were *D. cayennella* and *D. impersonatella* in lesser numbers. Mr. Pickles has since found *D. canella* breeding in *Paspalum densum* on a moist part of the Piaco (Piarco) Savannah in Trinidad.

Diatraea impersonatella, Walk. This, by far the most important economic species in Trinidad, has a very wide distribution and might almost equally well be included among the riparian forms, since it occurs (very sparingly) in the *Paspalum fasciculatum* beds of the Apure and in *Paspalum arundinaceum* (a new host-plant) on the margins of the Rupununi River, at its mouth. It was found also in *P. virgatum*, a favourite host, growing on the flood-cleared margins of the Napi Creek within the forest at the foot of the Kanuku Mountains. The latter grass is frequent in house-clearings and beside landings along the lower Amazon (chiefly within the limits of the estuary forest), and on the lower Rio Branco as far up as the mouth of the Catrimani River. On the former river it was often attacked by *D. impersonatella*, on the Rio Branco apparently not. This borer occurred in the same host at Rupununi Mouth on a similarly artificial clearing.

On the Rupununi savannahs, both north and south of the Kanuku Mountains, namely at Parika and at Shiriri Mountain, *D. impersonatella* occurred in the vegetation of the baixas described in the preceding section on *D. canella*. The main hosts were *Paspalum densus* and *P. millegrana*, and a less frequent one, *Andropogon bicornis*. Lower down the Takutu River, towards its mouth, in the Rio Branco savannahs, inadequate material was cut from *P. millegrana*; but as no moths were reared the attribution to this species is not certain.

On a small isolated savannah of the Pakaraima Mts., some 30 miles from the edge of the Rupununi plains, *D. impersonatella* larvae were found in *Paspalum plicatulum* along the bank of a creek flowing into the Ireng River. Finally, at an elevation of 4,400 feet, at the margin of a small savannah creek on the slopes of Mount Roraima, the same borer was collected in a new host-plant, *Axonopus scoparius*.

In no case has *D. impersonatella* been found in sugar-cane save in the British Guiana coast-lands and in Trinidad; with one exception—a new provision-field of a Wapisiana Indian in virgin rain-forest on Shiriri Mountain, Rupununi Savannahs. Here it was associated with *D. saccharalis*, both in very small numbers, in the first crop of canes.

A very peculiar feature is the abundance of this borer in *Paspalum fasciculatum* in Trinidad contrasted with its scarcity therein on the Apure, and its apparent absence from the luxuriant beds of this grass on the lower Amazon, though it occurred frequently in *P. virgatum* in artificial clearings in the neighbourhood of Pará and up to Jararaca—that is, within the limits of the estuary forest as delimited by Huber, and before the moré beds reached any great development. From this estuary region, right up to the mouth of the Rio Branco, where we made a special examination of much luxuriant *P. virgatum*, this host occurs not infrequently at landings and house-clearings, but *D. impersonatella* is apparently absent till the savannahs of the upper Rio Branco are reached. It is only fair to add that these *D. impersonatella* from the estuary region have been determined by Mr. Box with some doubt.

Diatraea savannarum, Box. This little species, which proved to be new, was reared from *Paspalum plicatulum* growing luxuriantly in the moister parts of the Rupununi Savannahs (British Guiana) about the base of Shiriri Mountain, especially along stream margins. The tiny larvae resemble in markings those of *D. albicrinella*, but the pronotal bar is weak and indistinct.

Diatraea cayennella, Dyar & Heinr. This species, of which larva and host-plant were alike unknown, was reared in small numbers, in association with *D. canella*, from *Andropogon bicornis*, on the edge of an aeta-palm grove on the Rupununi savannah. The larva, which I did not recognise as *Diatraea*, is of a unicolorous yellowish colour, with the black gut showing through the skin, and a darker yellow, small, pointed head.

5. Domestic Species.

For want of a better term I have called *D. lineolata* a domestic species. Assiduous search has so far not revealed its presence in any wild host-grass, whether naturalised or indigenous, in any part of its very extensive range. It is very closely attached to maize, which is itself the product of long domestication originating in the mists of antiquity and is unknown in the wild state. *D. lineolata* is the only well-studied insect species I can call to mind which is confined to a cultivated host-plant.

The extreme isolation and specialisation of maize, as a botanical species, considered as evidence of very long domestication, has lately been adduced as a reason

for crediting the Central American civilisations with much greater antiquity than archaeology at present is inclined to suspect. If, as seems likely, that time has been sufficient for the evolution of a new and very distinct insect species, then we have certainly another reason for considering it very long indeed.

6. Discussion of Economic Species.

Diatraea lineolata is, as we have seen, solely a maize-pest. Of the other eleven species mentioned, five have been recorded as attacking sugar-cane, all of these being at times locally severe. *D. saccharalis* is a major pest of cane throughout the West Indies and the Guianas, less so in Trinidad, where *D. impersonatella* largely takes its place. *D. canella* is the second most important species in the same area as far north as St. Lucia. *D. busckella* is the major species in the cane-fields of northern Venezuela and Colombia (Santa Marta). *D. albicrinella* we have found as a cane pest at one station on the Amazon (Paraná da Eva).

I have frequently drawn attention to the fact that the cane frog-hopper (*Tomaspis saccharina*) is a forest insect, and its very considerable adaptation to cane-field conditions in Trinidad has been adduced as evidence that those conditions have more in common ecologically with a rain-forest than with grassland. The large cane-borer (*Castnia licoides*) is also unquestionably a forest insect; so too are the secondary cane weevils, *Metamasius* spp. The chief *Diatraea* of cane, *D. saccharalis*, is also unknown under savannah conditions, but any ecological conclusions drawn from this colonisation of cane-fields by forest and riparian forms are rendered somewhat dubious by the discovery that *D. canella* and *D. impersonatella*, both serious cane-pests, are almost certainly of savannah origin.

7. Summary.

1. The survey of *Diatraea* spp. in their primitive habitats has been extended to cover the interior Guiana plateau, the Rio Branco, the lower Rio Negro and the lower Amazon.
2. The greatest practical result has been the discovery and introduction into British Guiana of the Amazon fly parasite (*Metagonistylum minense*) of *D. saccharalis*.
3. The most interesting ecological result was the finding of several *Diatraea* spp. as original members of a true savannah association.
4. The twelve species considered are grouped as forest, riparian, savannah and domestic species.
5. The two forest species are *D. bellifactella* and *D. brunnescens*.
6. Riparian grass associations are developed over huge areas on the lower Amazon, where they may be divided roughly into three main zones, dominated by *Paspalum repens*, *Echinochloa polystachya* and *Paspalum fasciculatum*, respectively.
7. The chief, and in fact only *Diatraea* of the first and second zones, is *D. saccharalis*, which is occasionally abundant.
8. The *P. fasciculatum* zone is colonised by *D. amazonica* and *D. myersi*.
9. The pure savannah species are *D. canella*, *D. impersonatella*, *D. savannarum* and *D. cayennella*.
10. *D. lineolata* is practically confined to maize, and no wild host-plants, either naturalised or indigenous, are known.
11. Five species attack cane, namely, *saccharalis*, *busckella*, *impersonatella*, *canella* and *albicrinella*, and all except the latter are major pests over considerable areas.

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EXPLANATION OF PLATE XIII.

- Fig. 1. Floating bed of *Paspalum repens*, Santarem, Amazon, in August.
- „ 2. Riparian bed of *Echinochloa polystachya*, near Santarem, Amazon, in October.
- „ 3. Riparian beds of *Echinochloa polystachya*, near Santarem, Amazon, in August. Collecting the Amazon fly parasite, *Metagonistylum minense*.
- „ 4. Riparian beds of *Paspalum fasciculatum* (left) and *Echinochloa polystachya* (right), near Santarem, Amazon, in October.
- „ 5. Riparian grass-bed chiefly *Paspalum fasciculatum*, with some *Echinochloa polystachya*, near Santarem, Amazon. The taller shoot (boy's left hand) is *E. polystachya*. October.
- „ 6. Consociation of young *Luziola spruceana*, Lago Grande, Santarem, Amazon, in October.



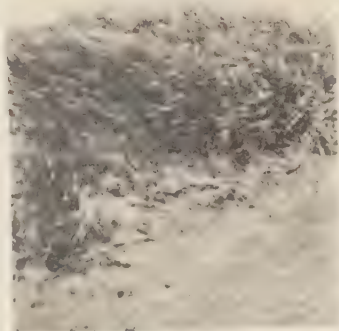
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PRIMITIVE HABITATS OF *DIATRAEA*
ON THE AMAZON

THE EFFECT OF INTERMITTENT STARVATION UPON THE DEVELOPMENT OF LARVAE OF THE MEADOW MOTH (*LOXOSTEGE STICTICALIS*, L.).

By J. S. SKOBLO,
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I. Introduction and Method.

The factors determining the duration of development of insects in the larva stage long ago attracted the attention of many investigators. The quantity as well as the quality of the food consumed by insects greatly affects the duration of this stage, but the numerous data on the subject are very contradictory. According to some investigators starvation accelerates development (Jeshikov, Peredelsky, Pastuchova), but others (Platova) found that starvation retards it. Several investigators have found that starvation may cause both of these effects; for instance, Krizhenetsky obtained such results when working with *Tenebrio molitor*. But it is very probable that these contradictions are due only to the fact that different regimes of starvation were applied. All those authors who, intentionally or unintentionally, used the regime of intermittent starvation, that is a regime in which periods of feeding alternate with periods of fasting, finally obtained retardation of development in the larval period. This has been established by the work of Seitz, Kopec, Platova, Sinitzky & Shekera, and many others. But none of the above mentioned investigators has expressed quantitatively the effect of intermittent starvation; usually the authors merely point out that the growth period was lengthened by several days. As a weak point in the methods adopted by them we may notice that no attention was paid to the separate instars of the larval period, and the latter was considered only as a whole; but it is not difficult to show that this omission may lead to errors. As an example we can take one of the latest works of Sinitzky & Shekera published in 1933. The authors experimented upon the same species as I did, namely, the meadow-moth (*Loxostege sticticalis*) and used larvae of the fourth and fifth instars, which they bred at 27°C., adopting the following regime of intermittent fasting (as used by Kopec):—(a) 2 days' feeding—1 day's fasting—2 days' feeding, etc.; (b) 1 day's feeding—1 day's fasting—1 day's feeding, etc.; and (c) 2 days' feeding—2 days' fasting—2 days' feeding, etc. As the separate instars were not taken into consideration, the fasting periods might occur at different periods of growth, hence the reaction to fasting might have been of very different kinds. This is clearly seen from the following examples.

(1) The larvae are deprived of food when they would naturally abstain from it owing to the approach of moulting. As shown by the experiments made by me during the autumn of 1933 at 27°C., the fourth instar lasts about 55 hours and natural abstention from food sets in at the 45th–50th hours. It is clear that if the larvae receive food during the first 48 hours and fast during the following 24 hours, such starvation will have no influence upon the duration of the 4th instar.

(2) The larvae are deprived of food during the second half or the last third of the present stage of development. In this case it is possible that the first 24-hour period of fasting would fall partly in the 4th instar and partly in the period of natural abstention from food after moulting in the 5th instar; the following period of feeding would then coincide with the natural beginning of feeding. In the following fasting period the larvae will already be in the last third of the development period of the 5th instar and at this time it is known that fasting does not retard but accelerates development.

(3) The larvae are deprived of food at the beginning of the stage. It is known that the susceptibility of larvae to fasting depends upon whether they have fed after moulting or not; obviously the starting point of the influence of intermittent fasting must greatly affect the duration of the growth of the larvae.

The frequency of similar errors of method is shown by the fact that no modern investigator is free from them. As a second example the work of Hoffmann, published in April 1933, may be quoted. Other cases might be mentioned, but these examples show sufficiently that it is absolutely necessary when making experiments to take into account the stages of development. Disregard of this condition leads to uncertain results which give no possibility of expressing quantitatively the retarding effect of intermittent starvation.

As the duration of each instar is very short in the meadow moth and at the optimal temperature the most protracted instar (the 5th) takes 60 hours, it seemed more rational in my own experiments, to shorten the periods of fasting and those of feeding. In separate series the larvae under experiment were fed for 2, 4, 12, 16 and 24 hours daily and fasted for 22, 20, 12, 8 and 0 hours respectively. Each larva was bred in a separate test-tube; observations were made 3-4 times a day or even more, and thus the time of moulting and the history of each larva under experiment were known with great accuracy. Moreover the amount of faeces excreted by the larvae was determined and enabled us to estimate the quantity of food taken during the instar; and after pupation each larva was weighed. This made it possible to determine the influence of fasting upon the fatness of the larvae, the weight of the pupae, the size of the moths and their fecundity. The experiments were carried out in the summer of 1933 in the experimental station of VIZR for the investigation of the meadow moth at the village Sadovoye, Kalmuck District.

It may be assumed that the duration of development of each larval instar will be determined by the duration of the fasting periods, the regime of feeding in the preceding instars, and by the instar subjected to the given regime; as it may be supposed that different instars will react differently to the same regime of starvation.

Undoubtedly external conditions (temperature, humidity, etc.) greatly affect the duration of development in the conditions of intermittent fasting. But this is a subject for special investigation; under the conditions in which the present work was carried out it was impossible to maintain constant temperatures. As most of the experiments, however, were carried out simultaneously and all the larvae were in similar conditions of temperature and humidity, we may be permitted to assume that the data presented reflect the real effect of intermittent starvation.

II. The Effect of the Duration of the Fasting Period.

We shall consider the influence of each of these factors separately. Table I represents the effect of fasting upon the duration of development of larvae in the fifth stage which received full feeding before the experiment. This table shows that the duration of development (calculated here only till the moment of natural abstention from food) is lengthened with the increase of the fasting period, and the longer the fasting periods and the shorter the feeding periods between them, the greater this lengthening. The table gives the mean figures. The greater the variations of development duration, the longer are the fasting periods, but they hardly ever overlap, as is seen from the following figures. In control batches with full feeding the development duration of the 5th stage ranges from 55 to 63 hours; with 12 hours fasting from 73 to 84 hours; with 20 hours fasting from 101 to 165 hours; and with 22 hours fasting every day the development duration ranges from 153 to 367 hours.

A point of great interest is presented by the fact that larvae are capable of enduring systematic starvation of great length, and though feeding only two hours

TABLE I.

Influence of the duration of the fasting period upon length of development of the 5th stage. (Feeding plant goose-foot).

Number of feeding hours a day	Development duration of the 5th stage in hours	Development duration in percentage
24 hours (control) ...	60.4 h.	100
12 "	79.2 h.	131
4 "	128.0 h.	212
2 "	229.5 h.	380

a day, they go through all the cycle of development and metamorphosis.* About 50 per cent. of the larvae bred under such conditions pupated normally and afterwards produced moths which on receiving additional food laid perfectly normal and viable eggs.

III. Influence of Feeding Regime in the preceding Stages.

Now we shall consider the influence of the feeding regime in preceding stages upon the length of development of the following stages. With that purpose let us compare the growth duration of the 5th stage as observed in three batches of larvae. All of them were starved for 12 hours a day, one batch having fasted only in the 5th stage, the second in the 4th and 5th, while the third fasted during the last three stages. From Table II, representing the results of these experiments, it may be

TABLE II.

Growth duration in the 5th stage in relation to the number of stages during which the larvae fasted 12 hours a day. (Feeding plant goose-foot.)

Stages during which larvae fasted for 12 hours a day	Growth duration			
	L. IV in h.	L. IV in %	L. V in h.	L. V in %
Control	60	100	60	100
5th stage	—	—	79	131
4th and 5th stages ...	56	93	88	147
3rd, 4th and 5th stages ...	96	160	127	211

seen that the amount of food in the preceding stages greatly influences the development duration of the following stages. These figures show a regular lengthening of the 5th stage corresponding with the increase in the number of stages subjected to a 12 hour daily fasting. The same lengthening of growth by 111–112 per cent. may be effected either by 20 hours fasting every day in the 5th stage alone or by 12 hours starvation during all the last three stages.

* It is necessary to remark that owing to a technical oversight the larvae of this batch of the second feeding fed 8 hours instead of 2. However, it does not alter the fact itself, as analogous results were obtained in the control batches.

IV. Effect of Starvation Regime upon different Stages of Development.

Puzirin, Sinitzky & Shekera have proved that the susceptibility of meadow moth larvae to starvation decreases with the age of the larvae. While in the first two days of life the larvae are capable of enduring only one day's fast, on the 8th-9th day of life they can endure fasting for four days. It is quite natural to suppose that the reaction of larvae to intermittent fasting will depend upon their stage of development. To ascertain this point let us compare the length of development of larvae in the 3rd, 4th and 5th stages each of which was subjected to 12 hours' fasting every day only on entering upon that stage. The data of these experiments are presented in Table III. Comparing the length of development of the 3rd and 5th stages we

TABLE III.
Growth duration of larvae in different stages when fasting 12 hours a day.

Feeding regimen	Growth duration		
	L. III	L. IV	L. V
Control	58 h.	60 h.	60 h.
Fasting 12 hours a day	118 h.	56 h.	79 h.
Growth duration as percentage of control	204%	93%	131%

see that the same amount of fasting caused a considerably greater retardation in the 3rd than in the 5th. It is a pity that we have no information as to the susceptibility to fasting of larvae in the 1st and 2nd stages; therefore we may assume (as a supposition only) that with the same fasting regime the younger the larvae the greater will be the lengthening of growth. However the table shows at the same time that intermittent starvation is liable to accelerate this development, though very slightly. The length of the 4th stage for a batch of larvae which has begun starving only at this stage is shorter by 4 hours (or 7 per cent.) than the control. The length of development of larvae at the 4th stage varied between 48 and 69 hours for the control batch and between 50 and 60 hours for the experimental batch. Larvae of this experimental batch did not take food after they had been fed for the third time, consequently normal abstention set in at the second period of starvation, *i.e.*, between the 36th and 48th hours of their development. Data available are insufficient to prove the acceleration of growth due to intermittent starvation, but they clearly show that different stages of the larval period react differently to the same starvation regime. This shows once more the necessity of an exact control of the stages during which the experiments are carried out. Thus we may consider as established that under intermittent starvation the rate of development of each stage in the larval period of the meadow moth depends upon the following factors: (1) length of starvation periods; (2) number of stages subjected to the given starvation regime, or else all the previous history of the larva; and (3) peculiarities of each stage.

IV. Intensity of Nourishment during Feeding Periods.

If the length of development shows a close connection with the duration of starvation periods, a similar dependence of the amount of faeces excreted on the number of feeding hours during each stage can hardly be established. This will be clearly seen from Table IV, which shows (1) the number of feeding hours, (2) the amount of excrement passed, and (3) the average excrement passed hourly during the 5th stage for three batches larvae which were starved in different degrees during the 5th stage only. Larvae fed during 12 hours a day received food 3-4 times,

those fed during 4 hours a day received food 4-5 times, and those fed for 2 hours a day got food 11-13 times. Owing merely to this fact there cannot exist any direct relation between the length of starvation periods and the quantity of excrement passed during a definite stage. The second reason for this inconsistency is the fact that the intensity of feeding, *i.e.*, the amount of food consumed per unit of time during feeding periods, does not decrease even when starvation is carried to a very

TABLE IV.

Effect of intermittent starvation length upon number of feeding hours, amount of excrement passed and average excrement per hour during the 5th stage. (Feeding plant goose-foot.)

Number of feeding hours a day	Number of feeding hours during the 5th stage	Amount of excrement passed during the 5th stage	Average excrement per hour during the 5th stage
24	56	268	4.8
12	43	239	5.5
4	18	82	4.6
2	25	180	7.2

high degree, but shows on the contrary a tendency to increase. This tendency will be clearly seen from Table IV, and still more clearly in Table V. In the latter table the average intensity of feeding for three batches of larvae may be compared: one batch, serving as a control, was fed continuously; the second batch was starved for 12 hours daily; and the third was starved for 22 hours daily. Roman figures indicate feeding periods which are of course of different lengths for each of the three batches. From the table it is evident that intensity of feeding of the starving larvae does not decrease and that it has, on the contrary, a marked tendency to increase as the length of the starvation periods increases. But as the food consumed during the feeding periods forms the source of excrements passed during starvation, the

TABLE V.

Effect of intermittent starvation length upon intensiveness of feeding duration feeding hours. (Feeding plant goose-foot.)

Number of feeding hours a day	Amount of excrement per hour					
	I	II	III	IV	V	VI
24	2.96	4.45	6.26	5.74	3.54	—
12	4.18	5.82	6.61	5.44	—	—
2	5.42	4.46	8.17	11.67	7.66	9.42

amount of excrement per hour must represent a unit expressing the amount of food consumed per unit of time during the feeding periods; this therefore may be calculated by totalling the amount of excrement passed during the starvation and feeding periods and dividing the sum by the number of feeding hours. However, as the size of the excrements passed during starvation periods is smaller, the estimated amount of excrement per hour of larvae fed for two hours a day will be somewhat exaggerated. One more point is to be noted from Table IV. Larvae fed for 4 hours a day had

18 hours of feeding for the whole 5th stage and passed about 82 excrements, which makes about 30 per cent. as compared with the control. Some of the specimens of this batch were fed for 14–13 hours during the whole stage and passed 60–65 excrements, *i.e.*, less than 25 per cent. of the control. This suggests that for the moulting process of the meadow moth larvae to be carried out there is no necessity for them to consume the amount of food they usually do, and that the beginning of moulting is not caused by their growth.

V. Importance of Nature of Food during intermittent Starvation.

In addition to the factors mentioned above the length of the larval period is greatly influenced by the nature of the food. Conditions of our work were such that there was no possibility of subjecting the food to chemical analysis; we were therefore confined to breeding larvae on different food-plants. The result of the experiments on intermittent starvation when feeding larvae on wormwood (*Artemisia maritima*) are given in Table VI. The effect of wormwood as a food-plant should be analysed as closely as has been done in the case of goose-foot, but lack of space

TABLE VI.

Effect of intermittent starvation on the length of development, number of feeding hours and the amount of excrement passed during the 5th stage, weight of pupae of larvae fed on worm-wood (Artemisia maritima).

Stages subjected to starvation effect				Number of feeding hours a day	Amount of excrement passed during the 5th stage	Amount of excrement as percentage of control	Development duration L V in hours	Development duration as percentage of control	Length of feeding during the 5th stage in hours	Length of feeding as percentage of control	Weight of pupae in mg.	Weight of pupae as percentage of control
Control	...	...	...	24	229	100	101	100	98	100	23.3	100
L. IV & L. V	...	...	...	20	220	96	116	114	91.5	93	18.8	77
L. III, L. IV & L. V	...	...	...	16	343	150	231	228	161	164	16.0	66

does not allow of such details, and we merely give a number of data indicating the importance of the kind of food-plant under conditions of intermittent starvation. Comparison in the control batches of the length of development of larvae fed on wormwood with that of those fed on goose-foot, both batches belonging to the 5th stage, shows us that this stage lasts in the first case 101 instead of 60 hours, which means that the development of the 5th stage of larvae fed on wormwood increases by nearly 70 per cent. as compared with those fed on goose-foot. This may be seen from the two following series. In the first series the larvae were fed for 20 hours a day and starved for only 4 hours; but in spite of this short period of starvation the average length of the 5th stage increased by 15 hours (*i.e.*, 14 per cent.). The following figures show that this increase was not merely accidental. The length of the 5th stage in the controls varies between 95 and 112 hours, while the experimental batch gives the following values: 75, 97, 120, 122, 123, 125, 134 and 134. In only one case is there an acceleration of development and in all the others a distinct retardation. Wormwood is the chief food-plant of the meadow moth larva in the places where it principally lives, and there is no doubt that larvae are subjected to starvation periods under natural conditions; for instance, at night when the

temperature falls, or when it rises excessively during the day. In the summer of 1933 on the Kalmuck Steppe the weight of pupae varied between 19 and 50 mg., and it seems possible that starvation of the larvae is one of the principal reasons for this great variation. Development of the 5th stage in the third batch of larvae that had been starved during the last three stages for 8 hours a day was longer than that of the corresponding batch fed on goose-foot. The 5th stage of this batch lasted for 231 hours, *i.e.*, for nearly 10 days, which proves the great importance of the nature of the food.

Larvae fed for 16 hours a day passed 343 excrements during the whole of the 5th stage; this figure is 50 per cent. higher than that of the control batch. Thus starving larvae passed more excrements, or in other words consumed more food than the control ones. This will be easily understood when we consider that during the 5th stage they were fed for 161 hours and that starving did not lower the intensity of feeding. However, the weight of the larvae (as Table VI clearly shows) steadily decreases as the length of the feeding periods decreases, and it is lowest in the larvae which passed the greatest amount of excrement. One might think that this systematic lowering in weight is due to a certain extent to the considerable increase in the general length of the stage; consequently, substances consumed by the larvae do not accumulate in their organism and are spent on their vegetative functions.

VI. Effect of Starvation upon the Weight of Pupae.

In a previous paper it was shown by me that the correlation between the weight of the pupae and the fecundity of the moths that they produce exceeds 80 per cent., so that a clear understanding of the factors affecting the weight is very important. The fact that the weight of the pupae is affected by the length of starvation emerges from Table VI, and there is no doubt that the number of stages subjected to starvation must also greatly influence this weight. Data given in Table VII show the effect of starvation that lasted for 12 hours a day upon the weight of pupae in three series of larvae. One series was starved only during the 5th stage, the second during the 4th and 5th, and the third during the last three stages. The table shows that the number of stages subjected to the same feeding regime greatly affects the weight

TABLE VII.

Dependence between weight of pupae and number of stages during which larvae were starved for 12 hours a day. (Food plant goose-foot.)

Stages of starving for 12 hours	Amount of excrement passed during the 5th stage	Amount of excrement as percentage of control	Weight of pupae in mg.	Weight of pupae as percentage of control
Control	268	100	45.2	100
5th stage	239	89	32.2	71
4th and 5th stages	232	87	27.8	61
3rd, 4th and 5th stages ...	270	101	18.7	41

of the pupae. Loss in weight in the first series amounted to 29 per cent., in the second series to 39 per cent., and in the third to 59 per cent. Decrease in weight of the pupae shows no simple relation to the amount of excrement passed, but larvae which had passed the greatest amount gave the smallest pupae. As was said before, the length of the 5th stage steadily increases as the number of stages subjected to the same feeding regime increases. One might also infer that the steady decrease

in weight is due to the greater part of the food having been utilised on vegetative functions.

The feeding regime was the same with all the three batches. The only difference consisted in different weights of the larvae at the time of moulting at the 5th stage, this difference being due to starvation during the previous stages. This fact enables us to assume that the original weight of larvae greatly influences their final weight, and that consequently the weight a larva has by the end of a given stage depends upon the weight it had at the beginning of this stage. From this conclusion it follows that if two larvae have different weights, their weights will continue different even if they are fully fed during that stage. These results are confirmed by those of Przibram in his article concerning the growth of *Tenodera aridifolia*, Stoll. On looking through Table VIII, which gives the weight of his larvae of the 7th, 8th and 9th stages, we may notice a definite correspondence between the original and the final

TABLE VIII.

Ratio of original weight of the 7th and 8th stages as calculated for larvae of Tenodera aridifolia, Stoll. (By Przibram).

No. of moulting	No. of larvae				Notes
	12	15	19	21	
7	0.6136	0.3562	0.3913	0.5092	Weight is given in gr.
8	1.3407	0.6423	0.7650	1.1659	

weights of the larvae during every stage. The larvae had been weighed by the author immediately after moulting before feeding began. Similar data may be found in a number of other articles concerning the growth of insects, but there is no doubt however that this problem is a rather complicated one and wants special study. If we are right in assuming that the final weight of larvae depends on their original weight, then starving, were it even during only one stage, will have some effect upon the weight of the pupae.

The weight of pupae formed by larvae fed on wormwood is considerably lower than that of pupae formed by larvae fed on goose-foot. This is probably due to the properties of goose-foot as a food, to higher temperatures during the period of the experiments, and probably to the fact that the wormwood (according to determinations carried out at the time) contained considerably less water. Thus the weight of pupae produced by larvae subjected to intermittent starvation is determined by (1) the length of the starvation period, (2) the number of stages subjected to starvation and consequently the whole process of the larval period, and (3) the properties of the food-plant.

The tables given above show great variations in the weight of pupae resulting only from intermittent starvation during the larval period. Similar and still greater changes have been obtained by applying other methods of starvation. The size of insects is closely connected with the weight of their pupae and consequently with the nature of their food during the larval period. With the insects in our experimental material the greatest length of the forewings varies between 6 and 12 mm. Similar variations in sizes of insects are observed in nature, as has been shown by a number of writers, and this suggests that the feeding regime and the amount of food consumed by the insects during the larval period are the principal factors determining the variation in the size of insects in nature.

At present data have accumulated in literature indicating that there exists no process in the life activity of insects which does not have some bearing on feeding,

which leads to the conclusion that food is an ecological factor of extreme importance which should be studied as thoroughly and as accurately as temperature, humidity and other elements of the surrounding medium have been.

Summary.

1. When studying the effect of intermittent starvation upon the length of development of the larval phase it is necessary to carry out experiments with each stage separately. Ignoring this factor and carrying out experiments on the larval phase as a whole results in serious errors.

2. The shorter the periods of feeding and consequently the longer starvation periods during each 24 hours the stronger their effect upon the length of development of each stage.

3. More than 50 per cent. of larvae fed only for 2 hours a day and starved for 22 hours accomplish their complete metamorphosis and produce moths that are fully capable of living.

4. The length of development of each stage depends upon the feeding regime during the previous stage. Using the same starving regime, development of the last stage is the longer the earlier the stage at which larvae were subjected to this regime.

5. At different stages of development larvae react differently to the same starvation regime. Thus starving for 12 hours a day increases the duration of the development of the 3rd stage by 104 per cent.; that of the 4th stage does not increase at all, while the development of the 5th stage increases only by 31 per cent.

6. Nature of food greatly influences the length of development under conditions of intermittent starvation. Starving for 8 hours a day when feeding larvae on wormwood results in greater increase of development than starving for 12 hours a day when feeding on goose-foot.

7. All factors influencing the development of the larval phase result in decreasing the weight of the pupae. Decrease in weight of pupae is the greater the longer the starvation periods and the earlier larvae were subjected to starvation effect. Nature of food also highly affects the weight of pupae.

8. Intensity of feeding during feeding periods of starving larvae does not decrease as compared to control. With very strongly starving larvae intensiveness of feeding even increases.

9. There is no direct proportion between the quantity of excrement passed, that is amount of food consumed and the weight of pupae. The longer the development, the more there are feeding periods and consequently the more excrement passed. Owing to the lengthening of development the most part of substances consumed are spent on vegetative functions; therefore there cannot exist direct connection between the number of excrement passed and the weight of pupae.

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AN IMPROVED AIR-PUMP FOR USE IN THE PRESERVATION OF LARVAE.

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The air-pump which is described in the present paper was designed in order to replace the rubber double-bellows type of inflator supplied with apparatus for use in the preservation of larvae. In the tropics, the life of articles manufactured from rubber is a comparatively short one, since rubber perishes if frequently handled, or even if stored, in spite of being packed in French chalk. The only rubber article necessary for use with this pump is tubing, which is easily replaceable. In Malaya, it has been found that the double-bellows type of inflator is unsatisfactory, owing to its rapid deterioration.

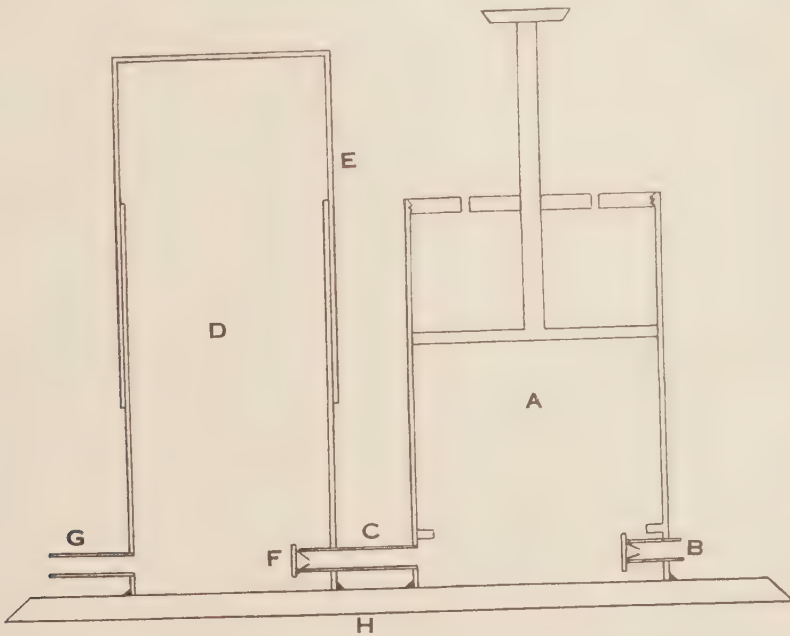


Fig. I.

The pump, as will be seen by the diagram (fig. 1) is of very simple construction and is therefore not costly to make. It consists of a metal pump, 50 mm. in diameter and 80 mm. in height (A), having a one-way air inlet-valve (B), near the base on one side. At the opposite side, near the base, the pump is connected by means of a short length of metal tubing (C) to a metal cylinder (D) of 40 mm. diameter and 80 mm. in height, having a well-fitting metal sliding jacket over it (E). The metal tube connecting the two cylinders has a one-way air inlet-valve (F) at the end farthest away from the pump. Opposite this valve is a tube (G) to which the glass tube that is inserted into the body of the larva is connected, the connection being made by a short length of rubber tubing. Both the pump and cylinder are fixed to a wooden or metal base (H) which may be either screwed or clamped on to a bench.

When the pump is operated, the sliding jacket on the cylinder is forced upwards and by its weight maintains a steady pressure of air while the larval skin is being dried in the oven. Oil may be applied to the inner surface of the sliding jacket in order to ensure a perfect fit.

A NEW SPECIES OF THYSANOPTERA FROM S. INDIA
(*TAENIOTHIRIPS CARDAMOMI*, SP. NOV.).

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(PLATE XIV.)

During a recent study of some insect and other pests of the cardamom plant in two or three tracts in South India, a new species of thrips was noted doing some appreciable damage to cardamom capsules on an estate in the Anamalai Hills, and this is described below.

Family THIRIPIDAE.

Taeniothrips cardamomi, sp. nov.

Macropterous Female.—Length 1.25 to 1.5 mm. General colour a mixture of greyish brown and pale yellow. Head and abdomen dark greyish. First two joints of antenna concolorous with head; 3rd, 4th and 5th pale yellowish white; 6th, 7th and 8th also similar but with a tinge of very light grey. Eyes black, ocelli clear but with no pigment. Mouth-cone pale grey. The thorax pale yellowish brown and the legs pale yellowish. Wings with the basal portion more or less transparent and the rest suffused with grey.

Head as broad as or slightly broader than long. The vertex forms a broad triangle in front of the eyes with the antennae rising from the sides of the triangle. Eyes large and faceted; ocelli arranged more or less in an equilateral triangle; one long bristle in front of each of the basal ocelli and another small one just posterior to the base of each antenna; a group of three small setae arranged in a curve behind the postero-inner corner of each eye. The cheeks are unarmed except for one small transparent bristle just behind each eye. The surface of the occiput behind the eyes has irregular transverse striae. Mouth-cone broadly pointed and reaching the middle of the prosternum. Antennae more than twice the length of head; first joint short, stout and cup-shaped; second longer and cylindrical; third longest of the joints, conspicuously stalked at basal region and broadening towards apex; fourth very slightly narrowed at base and almost of the same breadth throughout; fifth narrow at base and widest at apex, where it is broadly connected with the sixth, which is broader at base and narrows towards apex; the seventh of even breadth, with a slight constriction towards middle; eighth in the form of a narrow elongated cone; third and fourth joints with forked trichomers.

Prothorax broader than long with a pair of fairly long bristles (inner one longer, 80 μ long) at each of the postero-lateral angles, and also a small inconspicuous transparent bristle at each antero-lateral angle; few (4 or 6) bristles in a line just below the anterior margin, four or five along the posterior margin between the two pairs of large bristles at each postero-lateral angle and two or three stray small ones on the surface of the pronotum; the mid dorsum of pterothorax with three or four small bristles. Front tibiae with a strong spine at inner side of apex, and the hind tibia with a row of sharp spines along the distal part of the inner margin, the apical one the longest. Wings well developed and reaching 7th abdominal segment. The front wing has about 14 or 15 spines along the costa, five or six setae at the basal region and two at the extreme apex of the upper vein, and only five setae along

the lower vein ; the hind margin is profusely fringed. Abdomen elongate, longer than head and thorax together, broadest at the middle, where it is as wide as the pterothorax ; a few minute spines on the dorsal surface of each segment, five or six in all, arranged in two lines ; the posterior segments well supplied with bristles ; while the lateral corners of the posterior margins of the segments show some fringes, the hind margin of the 8th has a distinct transverse ciliary fringe ; the 9th segment with four long spines in front of the apical margin and one long one on each side of the segment projecting conspicuously on each side ; the last segment with two long spines mid-dorsally and one on each side ; there are also smaller bristles between and near these.

Measurements of holotype Female.—Total length 1.408 mm. ; head : length 0.154 mm., breadth 0.154 mm. ; prothorax : length 0.132 mm., breadth 0.198 mm. ; pterothorax : length 0.286 mm., breadth 0.264 mm. ; abdomen length 0.770 mm. Antennal joints in μ : (1) 25, (2) 40, (3) 80, (4) 70, (5) 50, (6) 60, (7) 20 and (8) 22.

Macropterous Male.—Length 0.9 to 1.0 mm., shorter and of a slightly lighter colour than the female, with the boundary lines between the abdominal segments darker. Antennal joints 3 to 8 uniformly pale whitish yellow. Abdominal segments 4 to 8 each with a median ovalish transparent patch (a feature characteristic of many males among thrips) ; apical segment ending bluntly and with conspicuous curved lateral spines.

Described from several females and males collected on diseased cardamom spikes and blossoms from the Puduthottam Estate, Valparai, 3,000 ft., Anamalai Hills, South India, December 1933 (T.V.R. No. 447). The insect was found attacking the buds and blossoms and causing dropping of the young buds or malformation of the capsules. Though there are many species of *Taeniothrips* recorded from South India, the only one with which this insect shows similarities is *Taeniothrips jonnaphila*, R., described by the author* a few years ago from material collected on sorghum, maize and sugar-cane shoots in different parts of South India. This species on cardamom can, however, be distinguished from *jonnaphila* by some important features :—(1) There is no marginal ciliary fringe on the 8th abdominal segment in *jonnaphila*. (2) In *jonnaphila* the head and prothorax are fringed with many more small setae than in *cardamomi*. (3) In *jonnaphila* the antennal joints are strongly armed with spines, while they are feebly spined in *cardamomi*. (4) The colour of the distal antennal joints in *jonnaphila* is distinctly dark brown. (5) The chaetotaxy of the wings is entirely different in the two species, *jonnaphila* having 13 setae and *cardamomi* only 5 on the lower vein of the forewing.

* Mem. Dept. Agric. India, (Ent. Ser. 10) 7, 1929, p. 256.

E A um

A NEW DISEASE OF CARDAMOM (*ELATTERIA CARDAMOM*) APPARENTLY DUE TO INSECT DAMAGE IN SOUTH INDIA.

By

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&

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(PLATE XIV.)

Introduction.

So far as the writers are aware, there is very little on record regarding insect pests of cardamom, especially of those affecting the growing crop, in India. This is chiefly due to the fact that this crop is grown only in some select forest areas, and we get very few opportunities of studying its diseases. The only insects so far recorded as casual pests of cardamom appear to be (1) the shoot-borer caterpillar (*Dichocrocis punctiferalis*, Guen.) recorded by Macmillan in 1925;* this is a well-known pest of castor, turmeric and ginger in the plains. (2) A capsule-boring Scolytid beetle, a minute dark brown insect boring in the capsules like the rice weevil; it is not quite clear from the available information in the records from Coorg whether this was noted as a pest of the growing crop or only in the stored dry capsules. (3) The cardamom borer, *Lampides elpis*, Godt.,† the pinkish caterpillar of a small blue Lycaenid butterfly which has been noted to attack the flowers and pods to a certain extent but not seriously. (4) A swarming caterpillar (*Eupterote* sp.)‡ which was once noted as causing substantial defoliation of the crop. (5) A white delicate lace-wing bug (*Stephanitis typicus*, Dist.), a minor pest also found on turmeric and ginger. A few others, like *Ischnodemus rochus*, Tol. (a bug) and *Hilarographa caminodes*, Meyr. (a root-boring caterpillar), have also been noted off and on; but none of them has ever attained the status of a serious pest.

In December 1934, a report was received of extensive damage done to the tender blossoms and pods of growing cardamoms on Puduthottam Estate, 2,500 ft., Anamalai Hills, South India, with the statement that "the damage is very extensive and is spoiling the appearance of fully 50,000 lb. of dry cardamom fruit." The disease was investigated by visiting the plantations, and a brief summary of the results of this study is presented in this paper, since the disease appears to be new and the insect that causes it has not previously been recorded.

Nature and Cause of Damage to the Pods.

Damage to the seed-pods generally appears in the shape of scalded or scabby patches on the skin, extending sometimes in streaks from the base to the top or occurring in scattered patches. They are of straw-brown colour and look like a corky encrustation. Several of these coalesce in severe types of damage, giving a very badly scabbed appearance. All the pods then, instead of looking green and shining, appear stunted, malformed and shrivelled, with gaping slits in the skin.

* H. F. MACMILLAN : Tropical Gardening & Planting. 3rd Edition (1925), p. 486.

† Cardamom.—Tropical Agriculturist, 70, 1929, pp. 166–169.

‡ K. KUNHIKANNAN : A serious pest of cardamoms.—Tropical Agriculturist, 64, 1925, pp. 40–41.

The seeds within show very poor development and lack the fine aroma of those from healthy pods. Such pods obviously command a very poor price in the market and consequently entail loss to the grower. Damage extends to the flower-stalks as well, resulting in a fair amount of shedding of pods and flowers that can only be detected by a trained eye.

It was at first presumed that the badly scabbed appearance of the pods might be the result of the fungus (or virus) disease that has been causing some havoc in the cardamom plantations on the hills for some years past. But it was found in this particular case that an altogether different and unsuspected agent was responsible for the scabbing, and Plate XIV gives an idea of the nature and extent of the damage done to the pods. On closer investigation it was discovered that the unhealthy patches on the skin were due to injury inflicted by a species of thrips feeding on the early, tender stages of the flowers and the pods, the creatures lacerating the tender green tissue and then sucking the juice. Where such injury was very severe owing to concentrated feeding by a large population of thrips, the tissue either turned brown and died or developed a corky layer as a result of the irritation set up. Injury of this type would then persist as a scab when the pod is fully developed. Since thrips seldom do damage to the pods after the latter have attained a certain size, scabbing on the pods noted in later stages is entirely due to the injury inflicted in the early blossom stage.

The Pest and its Habits.

The species of thrips noted is dark greyish brown in colour and was found to occur in numbers inside the bracts, perianth leaves, the unopened flowers, on the main peduncle and in the spindle of the top shoots. Various stages of thrips, *i.e.*, nymphs, prepupae and pupae, are found within the perianth round about the ovary; these stages are sluggish and glassy transparent in appearance, and their movements are sinuous. Adults are also comparatively sluggish and rarely take to flight. This thrips appears to be not one of the purely blossom-infesting types, and occurs also inside the spindle of the top shoots, but not in such large numbers. It has proved to be a new species, and the senior author has described it above (p. 357) under the name *Taeniothrips cardamomi*, sp. n.

Probable Factors influencing the Incidence of the Pest.

In normal years damage to pods is quite negligible and is said not to exceed 7 to 10 per cent., but last year the damage was computed by the planters to be somewhere near 90 per cent. In heavily infested panicles 6 to 7 nymphs and 2 to 3 adults were quite common round each ovary of a flower, and with such a population the panicles were reduced to a dirty brown mass of straggling bracts. The dry and warm weather experienced since November must have proved ideal for the rapid multiplication of the thrips, and an unusually large population must have resulted, with the consequential severe damage noted above. It may be interesting to record here the occurrence of another species of thrips in swarms on coffee and tea towards the end of April. This strengthens our assumption that this year especially must be regarded a "thrips' year" on account of the continued drought since November last.

Thrips continue breeding on the shoot till the flowers appear with the monsoon; they then migrate to the more suitable situations which the flowers offer. To begin with, there may not be many thrips to cause damage on a large scale, and hence the first few pickings always escape damage rather lightly. With warm weather setting in and continuing, there is an increase in the thrips population resulting in greater damage to the pods in the November and December pickings. With the absence of natural enemies and a continuance of favourable weather, thrips are able to reach pest proportions quite rapidly.



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CARDAMOM THRIPS

The only other host-plant that has been observed to harbour the pest is a grass, *Panicum longipes*.

In view of the recent findings that thrips can act as vectors for virus diseases, we suspect that this thrips may be playing the part of a vector in transmitting the mosaic disease which is prevalent on a few estates in the hills and is adversely affecting the plantations there.

Control Methods.

This is the first time that damage on such a large scale has been noticed, so that no control measures have been tried hitherto. Nicotine washes in the form of nicotine or nicotine sulphate were advised to be sprayed just at the time of blossoming to secure effective control of the thrips before they can harm the blossoms, and the results are being awaited.

There is great need for further investigation and collection of data on the aetiology of this new disease before one can come to any definite conclusions.

A PORTABLE STABLE TRAP FOR CAPTURING MOSQUITOS.*

By E. H. MAGOON.

(PLATE XV.)

The stable trap,† as introduced into Jamaica for capturing adult mosquitos, is a small screened building with openings which trap the mosquitos that enter in search of the domestic animal confined inside. Such traps are used by malaria control workers to learn the relative importance of different mosquito-breeding areas and the kinds of *Anophelines* to be found in areas where control work is contemplated, and also for a general check on the effectiveness of control measures.

A detailed description of a portable type of stable trap is given here for the benefit of field workers in malaria control who may require a similar trap for *Anopheles*. The pictures and drawings should make it possible for a carpenter to construct this trap with a minimum of supervision. The plans were prepared to conform to the type of trap long in use by the Health Department of Puerto Rico. Inspection trips of health-workers to and from Puerto Rico, rather than reports on these traps, have led to their use in several West Indian Islands, in Colombia, and in Panama.

The Jamaica portable trap has dimensions which require a minimum of wire cloth and galvanised sheets. It has the advantage of being easily taken apart to make it portable. The wooden framework of the top and of the four wall sections is shown (Plate XV, fig. 1). The lumber used is cedar; yellow pine is stronger and less expensive but is subject to rapid destruction by termites.

The roof and lower panels are covered with a total of $8\frac{1}{2}$ yards of 30-inch, 26-gauge, continuous, galvanised iron roofing. The upper panels are covered with a total of $4\frac{1}{2}$ yards of 36-inch, 16-mesh, steel wire cloth. A more durable screening, fine enough to prevent the escape of Jamaica *Anophelines*, would have but 12 meshes per lineal inch of bronze wire 0.02 inch in diameter. The completed trap is shown in Plate XV, fig. 2.

The trap, which is 6.5 ft. by 3.5 ft. in floor plan, may be shipped from one place to another as five separate units, and its erection is a simple matter. The bolts which hold the sides to the end sections are provided with wing nuts, so that no wrench is needed. The roof is fastened into place by means of long wire nails which are inserted into bored holes that extend horizontally from a piece of the roof into the adjoining inclined strut of the end walls. Plate XV, figs. 3 and 4, show the same trap being taken apart. An isometric drawing of the trap is given in text (fig. 1). Detail drawings are given in the text (fig. 2), and a list of the materials required to make one trap are given in an appendix.

The best domestic animals for stable traps in the West Indies and Central America are calves, donkeys, mules, and horses. The *Anophelines* detect the presence of these animals probably by the sense of smell and seek them much more readily than they seek humans. There are isolated places where the *Anopheles* are not attracted by a horse or mule, very likely because of a locally developed preference for human blood.

* The studies and observations on which this paper is based were conducted with the support and under the auspices of the International Health Division of the Rockefeller Foundation and the Central Board of Health, of Jamaica.

† The stable trap referred to in this paper was used first in 1923 by Dr. George C. Payne in Haiti at the suggestion of Dr. H. H. Howard. It was then introduced into Puerto Rico and underwent further development and refinement in the hands of Dr. Walter C. Earle.

or mules. These "animal catches" are successful because the important local *Anophelines* lodge themselves on the animal, from which they can be gathered in a collecting tube containing chloroform. This method is improved considerably by the use of a stable trap, for the following reasons:—

(1) The "catch" of the trap is more uniform owing to the fact that it is larger and operates during the entire night, whereas a short period of observation on a tethered animal may or may not coincide with the principal times of flight of the mosquitos, since these occur at varying times during the night, possibly depending upon the weather and the distance from the breeding-place.

(2) With traps, one inspector and an assistant can get simultaneous and more comparable data from a number of areas, whereas without traps the same personnel can perform an "animal catch" in only one of the areas at a time.

(3) Night work for the staff is eliminated.

(4) It is possible to display the trap catch of live mosquitos to persons who would not take the risk or undergo the discomfort of participating in the night "catch."

It is difficult for an inspector of mosquito-breeding in seasonal or tidal swamps to present his data of larva catches in such a way that they show the correct picture of the fortnightly variation in mosquito-breeding. The ditching of a swamp may destroy large areas of breeding-places where *Anopheles* larvae develop without partial control by fish and other agents which prey upon the aquatic stages of mosquitos when in open ditches. However, it may be possible to collect more larvae in a unit of time when the potential breeding-places have been reduced to some algal growths in the ditches in which relatively few larvae survive the disturbance occasioned by rainstorms, abnormal tides, or larvicides. Hence where extensive swamps are concerned, the adult "catches" data give the more dependable or better understood warning of the danger of *Anophelines* invading residential areas.

In some places stable traps are set up in positions outside the towns and used once a week for a "catch" of *Anopheles* to be identified and recorded. In other places parts of such a trap would be stolen if the trap appeared to be abandoned for a few days. Well-cared-for traps in continuous use are less likely to be damaged by thieves.

An illustration of the need for shifting a few stable traps over a large district is found in the work of the Health Departments of Kingston and St. Andrew. These have large areas in which *Anopheles albimanus* may develop at one season or another and produce serious outbreaks of malaria. The "catch" from stable traps placed at no less than fifty stations would give comparable information with regard to the emergence of *Anopheles* from the potential mosquito breeding-places scattered along the sea-coast from 10 miles east to 7 miles west of Kingston. Each portable trap can be used at five different stations each week. Six traps are required if fortnightly "catches" are to be made at each of over fifty stations. Without stable traps the present staff for inspection work cannot cope with the problem of learning when new control work is necessary.

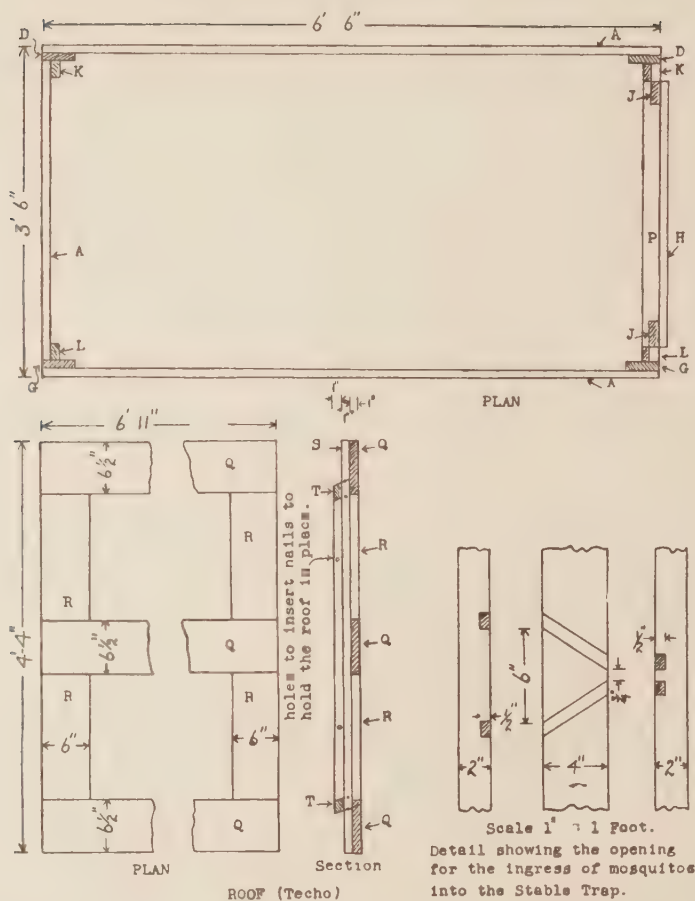
The following instructions were proposed for the operation of the stable traps in Jamaica:—

A. Selection of a site for a "catch":—

1. Place the trap where it will furnish the only source of blood for mosquitos in the immediate neighbourhood.

2. Face the door of the trap toward the west or in such a direction that mosquitos will not seek to leave the trap at sunrise.

3. Seek locations for the trap along the route taken by mosquitos when flying low from a swamp toward a residential area.



MOSQUITO TRAP STABLE TYPE

SCALE: 1" = 2 FEET EXCEPT AS SHOWN.

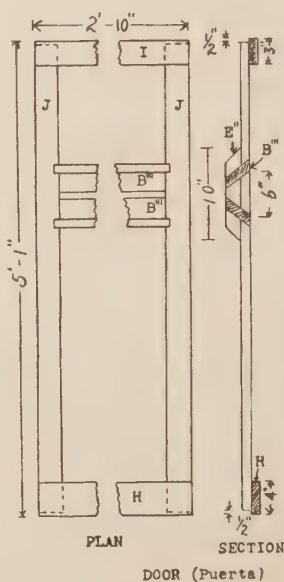
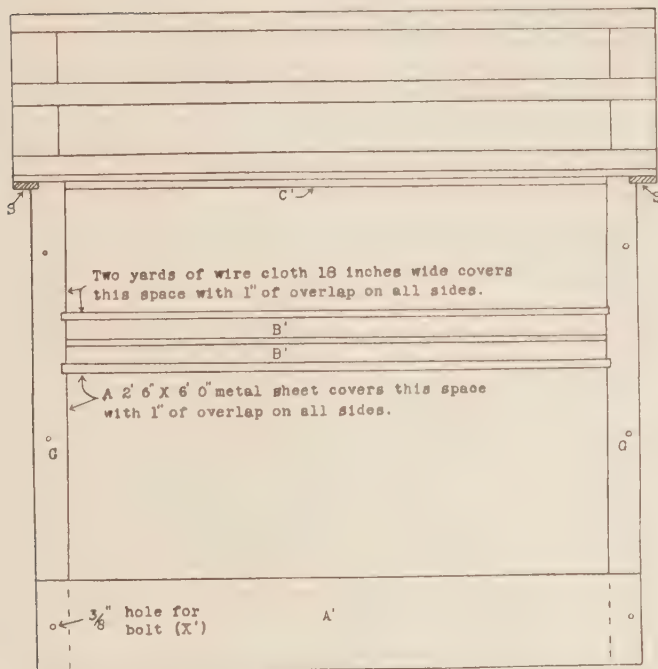
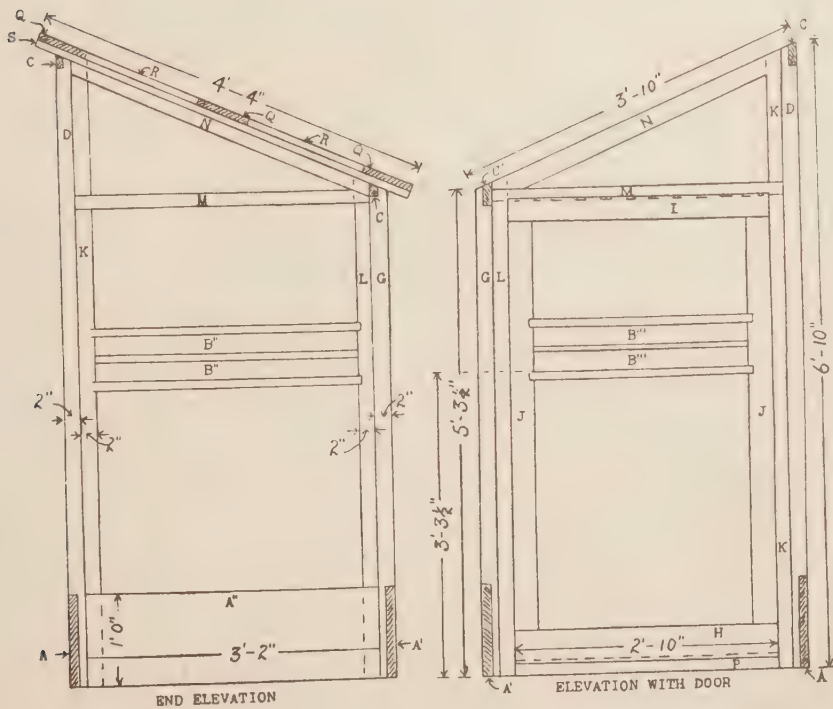


Fig. 2. See appendix for list of material and index to letters.



ELEVATION



ELEVATION WITH DOOR

B. Selection and care of the animal placed in a stable trap :—

1. Limit the selection of animals to calves, donkeys, mules, or horses.
2. Select docile animals that will not be restless inside such a trap.
3. Place fodder in the trap, and after giving the animal water to drink, lock it up in the trap before sunset.
4. Remove the animal from the trap soon after sunrise, repairing any damage to the screens.
5. If there is to be any delay in removing the mosquitos from the trap, insert wooden cleats or paper to close the slots provided for the entrance of the insects.

C. Collection and reporting of mosquito catches :—

1. It is desired to know the number of *A. albimanus*, *A. grabhami*, *A. vestitipennis*, or *A. crucians* mosquitos that enter the trap during a night. Hence the report of the catch should indicate any variation from the established procedure.

2. The report of a mosquito catch should give the name of the inspector, the date, the location of the trap or its designated letter and number if it is a regular catching station, the direction and strength of the wind, storms, and the numbers of mosquitos caught if such information is required by the separate instructions.

3. When the *Anopheles* mosquitos caught in the trap are to be killed and identified, they are carried in a wide-mouthed glass jar closed with a piece of gauze held with a rubber band. The gauze has a slit just large enough for the insertion of a glass-rod collecting tube. A little piece of cotton wool entirely closes the slit.

4. A useful collecting tube, with which to capture the mosquitos to be found resting on the screens inside a trap, is made with 12 inches of not less than $\frac{3}{16}$ -inch glass tubing and 18 inches of rubber tubing. A piece of gauze is placed over the end of the glass tubing before it is inserted into the flexible tubing. Mosquitos are sucked into the glass tube, from which they are blown into the screened collecting jar.

Summary.

An illustrated description is given of the construction details of a stable trap in Jamaica to catch Anopheline mosquitos. This trap is of knock-down type, which is more portable than many traps used for the same purpose.

Mosquito "catches" from stable traps are a means of obtaining information for planning anti-Anopheline work in a new area. These "catches" can be carried out with regularity and can give data to indicate the need of strengthening control measures to deal with the seasonal emergence of different mosquitos in specified zones.

The area in which the Health Officer of Kingston requires information about the prevalence of Anophelines is so extensive that nearly fifty regular mosquito-catching stations should be visited at least twice a month. In order to obtain the needed data with the present staff, the writer recommends the simultaneous use of six portable stable traps.

APPENDIX.

*Material required for Mosquito Trap.**Roof.*

- Q. 3 boards $1'' \times 6\frac{1}{2}'' \times 6' 11''$.
 S. 2 laths $1'' \times 2\frac{1}{2}'' \times 4' 4''$.
 U. 2 scantlings $2'' \times 2'' \times 3' 6''$.
 R. 4 boards $1'' \times 6\frac{1}{2}'' \times 1' 4''$.
 T. 2 scantlings $2'' \times 2'' \times 6' 2\frac{1}{2}''$.
 V. 2 pieces No. 26 gauge galvanised sheet roofing $2' 6'' \times 7' 5''$.
 Nails, screws and tacks.

Higher Side Wall.

- A. 1 board $1'' \times 12'' \times 6' 6''$.
 C. 1 scantling $2'' \times 3'' \times 6' 6''$.
 E. 2 blocks $2'' \times 2'' \times 10''$.
 W. 2 yds. wire cloth $36''$ wide.
 B. 2 boards $1'' \times 5\frac{1}{2}'' \times 5' 11\frac{1}{2}''$.
 D. 2 scantlings $2'' \times 4'' \times 6' 10''$.
 F. 1 sheet galv. iron $2' 6'' \times 6'$.
 Screws, nails, tacks and $8-\frac{5}{16}''$ bolts.

Lower Side Wall.

- A'. 1 board $1'' \times 12'' \times 6' 6''$.
 C'. 1 scantling $2'' \times 3\frac{1}{4}'' \times 6' 6''$.
 E'. 2 blocks $2'' \times 2'' \times 10''$.
 W'. 2 yds. wire cloth $18''$ wide.
 B'. 2 boards $1'' \times 5\frac{1}{2}'' \times 5' 11\frac{1}{2}''$.
 G. 2 scantlings $2'' \times 4'' \times 5' 4\frac{1}{2}''$.
 F'. 1 sheet 26 galv. iron $2' 6'' \times 6'$.
 X'. Screws, nails, tacks and $6-\frac{5}{16}''$ bolts.

Door.

- E''. 2 blocks $2'' \times 3'' \times 10''$.
 I. 1 board $1'' \times 3'' \times 2' 10''$.
 Y. 2 wooden buttons (latch).
 Z. 1 small hasp, staple, padlock,
 1 pr. $3''$ T hinges, screws,
 nails, tacks.
 H. 1 board $1'' \times 4'' \times 2' 10''$.
 J. 2 boards $1'' \times 3'' \times 4' 11''$.
 2 strips $\frac{1}{2}'' \times 1'' \times 4' 11''$.
 2 strips $\frac{1}{2}'' \times 2'' \times 2' 10''$.

End Walls.

- A''. 1 board $1'' \times 12'' \times 3' 2''$.
 B'''. 2 boards $1'' \times 5\frac{1}{2}'' \times 2' 5\frac{1}{4}''$.
 L. 2 scantlings $2'' \times 2'' \times 5' 5\frac{1}{4}''$.
 N. 2 scantlings $2'' \times 2\frac{1}{4}'' \times 3' 6\frac{1}{4}''$.
 F''. 2 sheets 26 galv. iron $2' 6'' \times 3'$.
 W''. 1 piece wire cloth $3' \times 1' 6''$ cut diagonally.
 W''''. 2 pieces wire cloth $3' \times 1' 6''$.
 B''. 2 boards $1'' \times 5\frac{1}{2}'' \times 2' 11''$.
 K. 2 scantlings $2'' \times 2'' \times 6' 9\frac{1}{2}''$.
 M. 2 scantlings $2'' \times 1\frac{1}{2}'' \times 3' 2''$.
 P. 1 scantling $2'' \times 2'' \times 3' 2''$.

EXPLANATION OF PLATE XV.

- Fig. 1. The completed wooden framework for a stable trap exhibited by the carpenter.
- „ 2. The completed trap set up where a donkey was the " bait " for a " catch " of three *Anopheles albimanus* and 800 *Culicines*.
- „ 3. Two men removing the roof from the stable trap preparatory to taking off a side section.
- „ 4. Partly dis-assembled stable trap. The wing nuts which cap three bolts can be seen through the open door.

SUCCESSFUL EXAMPLES OF BIOLOGICAL CONTROL OF PEST INSECTS AND PLANTS.

By Dr. HARVEY L. SWEETMAN,*

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The selection of examples where the biological control method has been successful depends somewhat upon the individual viewpoint.† A casual perusal of the literature would lead one to believe that predators and parasites had been unusually successful against many pests. In a recent communication from H. S. Smith it was stated: "If you go over the old literature on this subject in California, you will find that the black scale problem was solved by the introduction of *Rhizobius* in 1890. It was solved again in 1900 by the introduction of *Scutellista*. But we still spend in excess of a million dollars a year in southern California on spraying and fumigation for this pest. The same was true in Hawaii. For many years it was stated that one of the greatest examples of successful biological control was that of the sugar-cane leafhopper by the egg parasites, *Paranagrus* and *Ooetetrastichus*. Later *Cyrtorhinus* was introduced with success, and it was admitted that control by the two egg parasites was not satisfactory. No doubt all these introductions were valuable and represent different degrees of control, each succeeding introduction resulting in a greater degree of control than previously existed. The difficulty lies in the absence of a satisfactory criterion by which to measure and record the relative effects of the introductions." A critical analysis of the data submitted to support the contentions for the early examples mentioned above is far from convincing. However, it should be recalled that the standards for measuring the success of biological control have undergone considerable change during the intervening period.

Undoubtedly, the decline in the ravages of a number of insect pests has been attributed wrongly to the artificial manipulation of parasites and predators, when this decline really was due to other factors. Frequently high percentages of parasitism and numerous specimens of beneficial insects have been observed and from such observations and data the conclusion drawn that the pest would have destroyed the crop from a commercial viewpoint if a particular enemy of the pest had not been introduced or liberated. Such evidence will not withstand critical analysis, but frequently no better data are available. It is very common during insect outbreaks to find high percentages of parasitism and predatism, but if the outbreak is very extensive no apparent good results. When the pests are scarce, previous high percentages of parasitism are often suggested as the reason for the absence. However, unless accurate data, usually for several years, in terms of real mortality and not apparent mortality are available, such conclusions are not warranted. In fact, it is very dubious if percentage alone can ever be considered critical. Having determined the real mortality produced by a given parasite or predator, and knowing the effective reproductive capacity of the organisms concerned, one is in a position to determine whether the reduction in a host population can be correlated with the prevalence of the beneficial species or not. By securing data of a similar nature regarding other destructive agencies, physical as well as biotic, it is possible to reach a rather definite conclusion regarding the effectiveness and importance of the various controlling factors. Apparently many workers have overlooked the fact that a number

* The writer is indebted for suggestions received from Dr. H. S. Smith, Dr. C. P. Clausen, and Dr. W. E. Hinds in the United States, Dr. David Miller in New Zealand, Dr. D. T. Fullaway in the Hawaiian Islands, Dr. Akiro Kamito in Japan, and Dr. F. G. Holdaway in Australia.

† Correspondence is encouraged from workers who may wish to delete or add examples to the list as prepared.

of destructive agents may be present in an environment, any one of which in the absence of the others, would have reduced the ravages of a particular pest. Thus it is possible in some instances, that certain parasites and predators under observation, although actually killing a high percentage of the host have merely replaced other resistances of the environment, and actually no particular benefit has been accomplished by the introduction.

An attempt has been made to select the most successful cases of control produced through parasitism and predatism. Only those cases which are unusually successful or decidedly beneficial are included. Probably most workers acquainted with the subject will agree with the examples offered, but some would wish to add many more instances as successful. Examples only temporarily or slightly successful as the reduction or near eradication of white grubs from a field by birds during cultivation are not included, since the results may be vastly different in fields near by or the following season. However, the exclusion of such temporary or local examples of control should not overshadow their importance, as it is possible that such instances of control in the aggregate are of greater importance than that of the examples given.

The table is divided into two parts: the first including examples wherein the beneficial species have eliminated the necessity of other control measures; the second, examples wherein the parasites or predators, or both, are usually, or largely, adequate, but some damage and even local outbreaks may occur.

It is evident that all of the examples occur on islands or insular-like regions. The pests in the adequate control group, with two exceptions, belong to the order Homoptera and are either scale-insects, mealybugs, aphids, or leafhoppers. These pests have certain characteristics in common, as being sedentary, slow in dispersal, gregarious, limited number of hosts attacked, etc., that seem to render them especially susceptible to the attacks of parasites and predators. However, among the highly beneficial group, some of the pests live in relatively inaccessible places and have habits that would seem less favourable to the attacks of enemy insects, yet the attacks of the beneficial forms seem to be almost as effective. This is especially encouraging since it demonstrates the feasibility of attempting parasite and predator control among pests living in quite varied, hidden, and even unusual habitats.

The beneficial insects belong to four orders, although more belong to the Hymenoptera than to the Hemiptera, Diptera, and Coleoptera combined. About one-fourth of the beneficial species listed are predators, thus showing the importance of predatory species in the biological control complex, a fact not generally recognised by entomologists.

In nearly all of the examples given, species other than those listed attack the hosts, but the principal parasites and predators are shown and in most examples are not appreciably aided by the species omitted. The predator, *Cryptolaemus montrouzieri*, until recently, was commercially controlling *Pseudococcus gahani*, although the beetles were unable to maintain themselves and were liberated as needed. About two years ago the Chalcid, *Coccophagus gurneyi*, completely replaced *Cryptolaemus* as the controlling agency, being more efficient as well as maintaining itself. The two cutworms, *Cirphis unipuncta* and *Spodoptera mauritia* are still troublesome at times, but the prevalence and frequency of outbreaks are enormously reduced by several parasites, of which the two most important are given.

It is worth noting that the most successful examples have been brought about by one parasite or predator in most instances. Among the pests listed, the cutworms, *Cirphis* and *Spodoptera*, come the nearest to indicating the partial success of a group of parasitic enemies, but this is the poorest example listed.

Attempts to control pest plants by the biological method have yielded some very interesting results, although not equal to those obtained against insects. However, a number of examples seem to fit into the highly beneficial group.

Highly Beneficial Control.

Pest Species	Order	Beneficial Species	Order	Family	Parasite or Predator	Countries
<i>Anomala orientalis</i> , Waterh. ...	Coleoptera	<i>Scolia manilar</i> , Ash. ...	Hymenoptera	Scolidae	Parasite	Hawaiian Islands
<i>Oryctes tarandus</i> , Oliv. ...	Coleoptera	<i>Scolia oryctophaga</i> , Coq. ...	Hymenoptera	Scolidae	Parasite	Mauritius
<i>Stagrus fulvitaris</i> , Pasc. ...	Coleoptera	<i>Ischiognathus syagrus</i> , Ful. ...	Hymenoptera	Braconidae	Parasite	Hawaiian Islands
<i>Diaspis pentagona</i> , Targ. ...	Homoptera	<i>Phospaltella berlesii</i> , How. ...	Hymenoptera	Aphelinidae	Parasite	Italy
<i>Perrisia pyri</i> , Bch. ...	Diptera	<i>Musocyclops ornatus</i> , Kieff. ...	Hymenoptera	Scelionidae	Parasite	New Zealand
<i>Cirphis unipuncta</i> , Haw. ...	Lepidoptera	<i>Euplectrus platyhypenae</i> , How. ...	Hymenoptera	Elachertidae	Parasite	Hawaiian Islands
<i>Spodoptera mauritia</i> , Boisd. ...	Lepidoptera	<i>Archytas cuphis</i> , Cur. etc. ...	Diptera	Tachinidae	Parasite	Hawaiian Islands
<i>Rhabdocnemis obscura</i> , Boisd. ...	Coleoptera	<i>Ceromasia sphenophori</i> , Vill. ...	Diptera	Tachinidae	Parasite	Hawaiian Islands
<i>Pseudococcus citri</i> , Risso ...	Homoptera	<i>Cryptolaemus montivagari</i> , Muls. ...	Coleoptera	Coccinellidae	Predator	California
<i>Eriococcus coriaceus</i> , Mask. ...	Homoptera	<i>Rhizobius ventralis</i> , Erich. ...	Coleoptera	Coccinellidae	Predator	New Zealand

EXAMPLES OF SUCCESSFUL CASES OF CONTROL BY BIOLOGICAL METHODS.
Adequate Control.

Pest Species	Order	Beneficial Species	Order	Family	Parasite or Predator	Countries
<i>Pseudococcus nipae</i> , Mask. ...	Homoptera	<i>Pseudaphycus utilis</i> , Timb. ...	Hymenoptera	Encyrtidae	Parasite	Hawaiian Islands
<i>Eulecanium coryli</i> , L. ...	Homoptera	<i>Blastothrix sericea</i> , Dalm. ...	Hymenoptera	Encyrtidae	Parasite	British Columbia
<i>Asterolecanium varicosum</i> , Ratz. ...	Homoptera	<i>Habrolepis dalmani</i> , West. ...	Hymenoptera	Encyrtidae	Parasite	New Zealand
<i>Pseudococcus filamentosus</i> , Ckll. ...	Homoptera	<i>Anagrus dactylopii</i> , Haw. ...	Hymenoptera	Chalcididae	Parasite	Hawaiian Islands
<i>Eniosoma lanigerum</i> , Haus. ...	Homoptera	<i>Aphelinus mali</i> , Hald. ...	Hymenoptera	Aphelinidae	Parasite	New Zealand, etc.
<i>Aleurocanthus spiniferus</i> , Quaint.	Homoptera	<i>Prospaltella smithi</i> , Silv. ...	Hymenoptera	Aphelinidae	Parasite	Japan
<i>Aleurocanthus woglumi</i> , Ash. ...	Homoptera	<i>Eretmocerus serius</i> , Silv. ...	Hymenoptera	Aphelinidae	Parasite	Cuba
<i>Pseudococcus gahani</i> , Green ...	Homoptera	<i>Coccophagus gurneyi</i> , Comp. ...	Hymenoptera	Aphelinidae	Parasite	California
<i>Gonipterus scutellatus</i> , Gyll. ...	Coleoptera	<i>Anaphoidea nitens</i> , Gir. ...	Hymenoptera	Myrmaridae	Parasite	New Zealand
<i>Leuana iridescens</i> , B.-Bak. ...	Lepidoptera	<i>Ptychomyia remota</i> , Ald. ...	Diptera	Tachinidae	Parasite	Fiji Islands
<i>Icerya purchasi</i> , Mask. ...	Homoptera	<i>Rodolia cardinalis</i> , Muls. ...	Coleoptera	Coccinellidae	Predator	California, New Zealand, Japan, etc.
<i>Aspidiotus destructor</i> , Sign. ...	Homoptera	<i>Cryptognatha nodiceps</i> , Mshl. ...	Coleoptera	Coccinellidae	Predator	Fiji Islands
<i>Perkinsiella saccharicida</i> , Kirk. ...	Homoptera	<i>Cyrtorhinus mundulus</i> , Bredd. ...	Hemiptera	Miridae	Predator	Hawaiian Islands

Highly Beneficial Control.

Pest Plant	Beneficial Organisms	Order	Family	Countries
<i>Opuntia inermis</i> ...	<i>Cactoblastis cactorum</i> , Berg. ...	Lepidoptera	Pyralidae	Australia
	Wet rots			
	<i>Dactylopius opuntiae</i> , Ckll. ...	Homoptera	Coccidae	
	<i>Tetranychus opuntiae</i> , Banks	Acarina	Tetranychidae	
	<i>Chelinidea tabulata</i> , Burm. ...	Hemiptera	Coreidae	
<i>Opuntia stricta</i> ...	<i>Cactoblastis cactorum</i> , Berg. ...	Lepidoptera	Pyralidae	Australia
	Wet rots			
<i>Opuntia streptacantha</i>	<i>Dactylopius opuntiae</i> , Ckll. ...	Homoptera	Coccidae	
<i>Opuntia tomentosa</i> ...	<i>Chelinidea tabulata</i> , Burm. ...	Hemiptera	Coreidae	
<i>Opuntia monacantha</i>	<i>Cactoblastis cactorum</i> , Berg. ...	Lepidoptera	Pyralidae	Australia
	Wet rots			
	<i>Dactylopius opuntiae</i> , Ckll. ...	Homoptera	Coccidae	
	<i>Dactylopius ceylonicus</i> , Green	Homoptera	Coccidae	
	<i>Dactylopius confusus</i> , Ckll. ...	Homoptera	Coccidae	
	<i>Chelinidea tabulata</i> , Burm. ...	Hemiptera	Coreidae	
<i>Opuntia imbricata</i> ...	<i>Dactylopius newsteadii</i> , Ckll.	Homoptera	Coccidae	Australia
<i>Opuntia dillenii</i> ...	<i>Cactoblastis cactorum</i> , Berg. ...	Lepidoptera	Pyralidae	New Caledonia
<i>Opuntia dillenii</i> ...	<i>Dactylopius ceylonicus</i> , Green	Homoptera	Coccidae	South India Ceylon
<i>Opuntia monacantha</i>	<i>Dactylopius opuntiae</i> , Ckll. ...	Homoptera	Coccidae	
<i>Opuntia dillenii</i> ...	<i>Dactylopius coccus</i> , Costa ...	Homoptera	Coccidae	Madagascar
<i>Opuntia tuna</i> ...	<i>Dactylopius opuntiae</i> , Ckll. ...	Homoptera	Coccidae	Mauritius
<i>Lantana camara</i> ...	<i>Crocidosoma lantanae</i> , Busck	Lepidoptera	Tortricidae	Hawaiian Islands
	<i>Agromyza lantanae</i> , Frogg. ...	Diptera	Agromyzidae	
	<i>Teleonemia lantanae</i> , Dist. ...	Hemiptera	Tingitidae	
<i>Cludemia hirta</i> ...	<i>Liothrips urichi</i> , Karny ...	Thysanoptera	Phloeothripidae	Fiji Islands

NEW HYPOGEIC MEALYBUGS (COCCIDAE) FROM EAST AFRICA.

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The following addition to the COCCIDAE consists of eleven new species which are assigned to the Pseudococcine genera *Rhizoecus* and *Ripersia*. A number of indigenous species of root-infesting mealybugs have been implicated with fungoid associates in the causation of certain root diseases of important economic plants in East Africa and the systematic description of hypogeic COCCIDAE in that area cannot fail to have economic significance.

I am indebted to Dr. A. D. Imms, F.R.S., for permitting me to work in his laboratory and for useful suggestions in the course of the work.

I also desire to thank Mr. E. E. Green for reading the manuscript and for comparing my specimens with types in his collection and for commenting thereon.

Genus *Rhizoecus*, Kunck.

Rhizoecus geniculatus, sp. nov. (fig. 1).

Adult female elongate, vermiform; segmentation distinct; derm powdered with white wax; anal tassels short, marginal tassels absent; body content milky white in colour; mature female enclosed in white waxy cells. Cerarii absent;

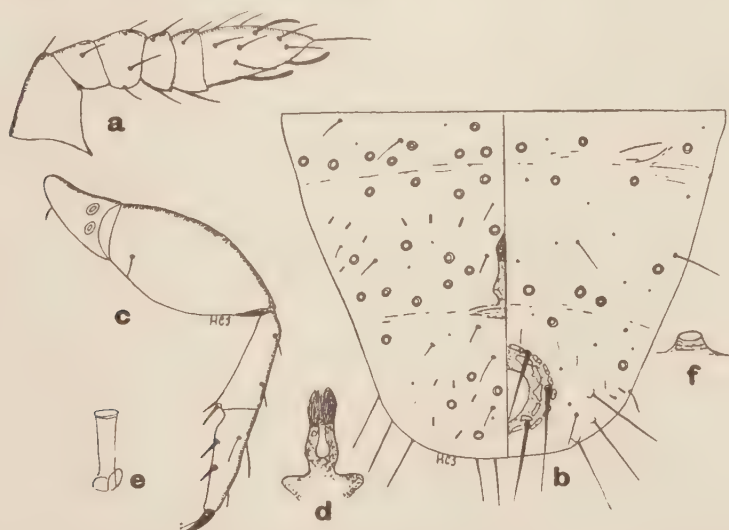


Fig. 1. *Rhizoecus geniculatus*, sp. n.: a, antenna ($\times 57$); b, posterior segments of abdomen ($\times 75.5$); c, foreleg ($\times 57$); d, genitalia ($\times 80$); e, posterior spiracles ($\times 68.5$); f, medio-ventral ostiole ($\times 80$).

dorsally on each side of anal ring three somewhat elongate subequal setae; anterior and posterior ostioles small but distinct; medio-ventral ostiole with a small central aperture having a rather broad sclerous rim (fig. 1, f). Body setae short and very sparse. Circular multilocular pores occur all over the derm; tubular pores of

extremely minute bore also open on the derm; trilobate pores absent. Antennae six-segmented, short and stout, geniculate, the bases fairly closely approximated, varying between 0.20 mm. and 0.30 mm. apart; the antennal segments in the following average proportions: (1) 8, (2) 4, (3) 5, (4) 3, (5) 3, (6) 12; the terminal segments enlarged and claviform; the terminal segment bears three stout falcate setae. Eyes small but distinct and fully formed. Rostrum dimerous, second segment the longer. Legs small and stout and not exhibiting wide variation in the relative lengths of corresponding segments.

		Trochanter	Femur	Tibia	Tarsus
Fore limb ...	...	9	18	12	11
Mid limb ...	...	9	18	13	11
Hind limb	...	9	20	16	12

A pair of irregularly shaped vacuoles present on each hind tibia; tarsi taper distally; claw without denticle; ungual digitules slightly longer than claw and knobbed; tarsal digitules absent. The anal ring cells consist of two concentric series; the inner series irregular in shape; the anal ring setae short and stout; anal lobes absent.

Length of body 1.38–2.00 mm.; breadth 0.63–1.02 mm.

Mr. Green informs me that this species differs from *R. halophila*, Hardy, in the markedly smaller limbs and in the smaller number of body setae.

Type host:—Roots of *Abutilon usambarense*, Gurke (Malvaceae).

Type locality:—Getitu, Nyeri, Kenya Colony.

Other records:—Roots of *Sida Schimperiana* (Malvaceae), Kikuyu Reserve, Kenya; roots of *Cynodon plectostachyum* (Gramineae), Kampi-ya-moto, Kenya; roots of *Digitaria abyssinica* (Gramineae), Eldoret, Kenya.

***Rhizoecus mabokoensis*, sp. nov. (fig. 2).**

This species is closely allied to *R. geniculatus* but can be readily distinguished by the fact that in the latter the terminal joints of the antennae are enlarged and claviform, whereas the form of the antennae in *R. mabokoensis* is subcylindrical; in addition, in *mabokoensis* each trio of paranal setae are grouped closer together and arise from a raised and slightly sclerotised area of the derm (fig. 2).



Fig. 2. *Rhizoecus mabokoensis*, sp. n.: a, paranal setae ($\times 75.5$); b, paranal setae ($\times 75.5$); c, antenna ($\times 57$).

Type host:—Roots and rhizomes of *Cynodon plectostachyum*, Pilg (Gramineae).

Type locality:—Athi River Station, Kenya.

Other records:—Roots of *Cynodon plectostachyum*, Maboko Rd., Machakos, Kenya.

Rhizoecus angustus, sp. nov. (fig. 3).

Adult female vermiform; segmentation clearly defined; derm dusted with white powdery wax; no tassels; ovisac cottony; body content milky white. Cerarii absent; anal ring very slightly recessed, forming two very small anal lobes; three or four subequal spines are present on each side of the anal ring, and there is a tendency for triangular pores to aggregate near their bases; in addition to circular multilocular pores, which occur on both dorsum and venter, trilobate pores are present principally along the margins; minute tubular ducts also present. Anterior and posterior ostioles small but clearly defined; a small medioventral ostiole present. Body setae very short and very scanty. Antennae six-segmented, geniculate, bases closely approximated; antennal segments in the following average proportions (1) 12, (2) 5, (3) 6, (4) 5, (5) 5, (6) 14; three falciform setae present on terminal segment and one on the penultimate. Eyes small and well formed. Rostrum dimerous; the distal segment about twice the length of proximal. Legs small but robust; each fore tibia with two spines at its distal extremity; the mid and hind tibiae each with three; a pair of subcircular vacuoles present on the outer aspect of each hind tibia; tarsi taper distally; each tarsus with two spines on its inner margin, claw long and slender; ungual digitules present and knobbed; tarsals absent.

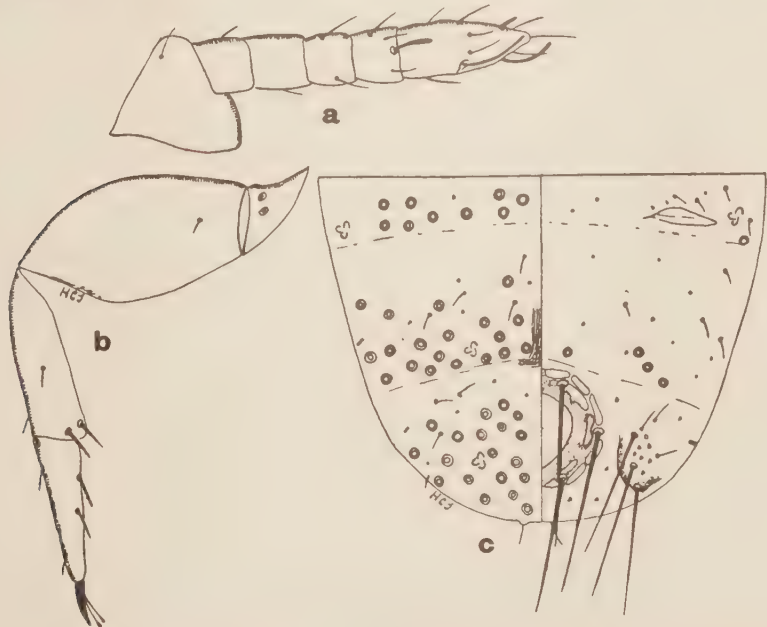


Fig. 3. *Rhizoecus angustus*, sp. n.: a, antenna ($\times 57$); b, fore limb ($\times 57$); c, posterior segments of abdomen ($\times 80$).

The average proportions of the segments of the limbs are:—

		Trochanter	Femur	Tibia	Tarsus
Fore limb	...	12	26	19	15
Mid limb	...	12	26	19	15
Hind limb	...	13	30	25	18

Length of body 1.50–1.80 mm.; breadth 0.70–0.73 mm.

This species can be distinguished from *R. dianthi*, Green, by its more slender antennae.

Type host :—Roots of *Leonotis nepetaefolia* (Labiatae).

Type locality :—Murera, Ruiru, Kenya Colony.

Other records :—Roots of *Kalanchoe glaucescens*, Britten (Crassulaceae), Ruiru, Kenya; roots of *Themeda triandra*, Forsk. (Gramineae), foot of Mt. Elgon, Kenya.

***Rhizoecus globosus*, sp. nov. (fig. 4).**

Adult female almost circular in outline, convex dorsally and flattened ventrally; indication of segmentation almost obliterated; ground-colour milky white; derm dusted with white powdery wax; enclosed in a white felted ovisac; oviparous, the eggs white. Cerarii absent; a trio of elongate spines present on each side of the anal ring, with which is associated a short auxiliary seta; a few short setae occur on frons and in the posterior ventral abdominal region; remainder of derm practically naked. Three types of dermal pores can be distinguished: (1) a number

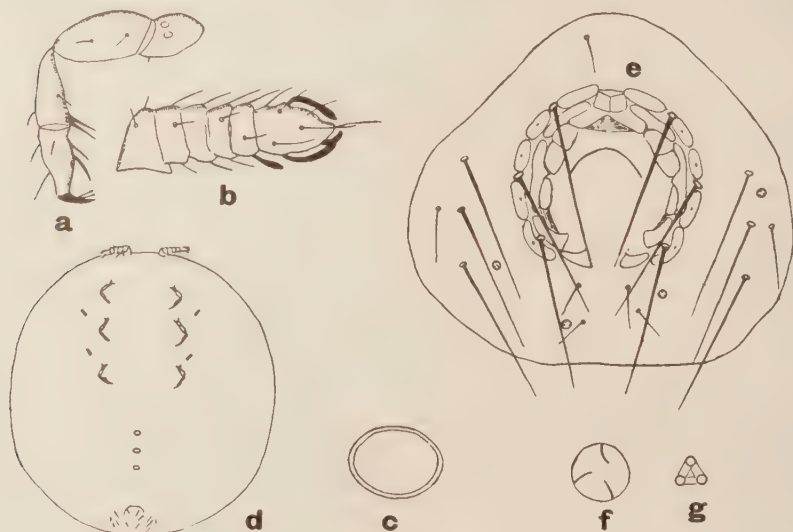


Fig. 4. *Rhizoecus globosus*, sp. n.: a, foreleg ($\times 57$); b, antenna ($\times 57$); c, a medio-ventral pore ($\times 87.5$); d, general outline of insect: legs, spiracles, medio-ventral ostioles and basal parts of antennae reflected through from ventral surface ($\times 95$); e, anal ring and paranal setae ($\times 95$); f, subcircular pore ($\times 160$); g, moruliform pore ($\times 100$).

of large subcircular pores occurring on dorsum and venter; (2) a number of moruli-form pores (fig. 4) arranged lineally and longitudinally in the marginal and median region; (3) a few small circular pores. Dorsal ostioles undetected; three ovoid-shaped orifices occur in linear arrangement in the midventral abdominal region. Antennae of the *Rhizoecus* type, geniculate, six-segmented, in the following proportions (1) 12, (2) 6, (3) 5, (4) 5, (5) 5, (6) 6; a few longish setae on each segment; the terminal segment with three stout falcate setae, which are somewhat swollen distally; a similar but smaller seta present on the fifth segment. No indications of eyes. Rostrum stout and dimerous; rostral loop short, not reaching region of

midlegs. Legs small relative to bulk of body but fully formed in the following average proportions :—

		Trochanter	Femur	Tibia	Tarsus
Fore limb	...	6	11	8	7
Mid limb	...	6	10	7	7
Hind limb	...	6	11	9	7

The distal extremity of each tibia dilated and bearing two stout spines ; each tarsus with two stout spines on inner margin ; ungual digitules knobbed, each slightly longer than claw ; tarsal digitules absent.

Length of body 1.36–1.50 mm. ; breadth 1.13–1.30 mm.

Type host :—Roots and rhizomes of *Themeda triandra*, For. (Gramineae).

Type locality :—Kitale, Kenya Colony.

***Rhizoeus incrassatus*, sp. nov. (fig. 5).**

Adult female almost circular in outline, highly convex dorsally and flattened ventrally, enclosed in waxy cell ; derm powdered with white wax ; no tassels ;

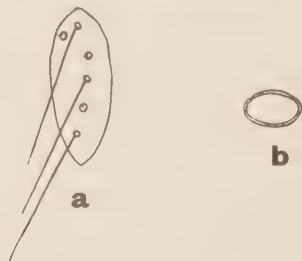


Fig. 5. *Rhizoeus incrassatus*, sp. n. : **a**, paranal setae ($\times 95$) ; **b**, medio-ventral pore ($\times 87.5$).

ground-colour milky white. The derm (especially of older specimens) is brittle and rather densely chitinised, and a distinct crackling sound is produced when the living insect is punctured.

This species is closely allied to *R. globosus* but may be distinguished by the following features :—(1) The derm is more densely chitinised especially in older specimens ; (2) it possesses only two medio-ventral pores and they are smaller than those of *R. globosus* ; (3) the paranal setae lack auxiliary setae ; (4) the setae on the frons and in the ventro-abdominal region are much scantier.

Length 1.17–1.84 mm. ; breadth 1.00–1.47 mm.

Type host :—Roots of *Pennisetum clandestinum*, Hochst. (Gramineae).

Type locality :—Kiamwere, nr. Nyeri, Kenya Colony.

***Rhizoeus immsi*, sp. nov. (fig. 6).**

Adult female vermiform ; body content white ; derm powdered with white wax ; ovisac not observed. The anal ring of the *Rhizoeus* type ; a trio of paranal setae present on each side of anal ring ; the two anterior pair of spines on each side surrounded by a chitinised area of the derm, the posterior spine on each side arising near a much smaller chitinised area ; the anal lobes absent. Small subcircular

pores common and generally distributed; circular multilocular pores present on dorsum and venter, especially around genital aperture; moruliform pores present both dorsally and ventrally along the margin, and a few very minute circular ducts

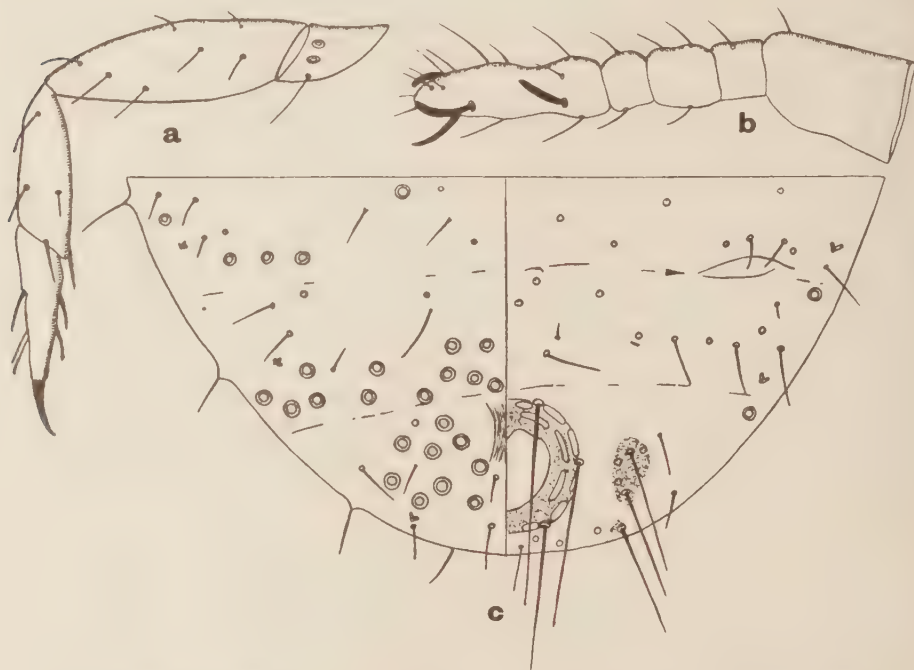


Fig. 6. *Rhizoecus immsi*, sp. n.: a, mid leg ($\times 57$); b, antenna ($\times 57$); c, posterior segments of the abdomen ($\times 75$).

also occur. Anterior and posterior dorsal ostioles small but distinct; medio-ventral pore with small central aperture and a rather broad sclerous rim similar to that of *R. geniculatus*. Antennae five-segmented, geniculate and with four stout falcate setae on the terminal segment. Eyes small, very protuberant and deeply pigmented. Legs relatively large; two sharp pointed spines at the distal end of each tibia, claw long and slender, digitules absent.

Length 1.38 mm.; breadth (under compression) 0.82 mm.

Type host:—Roots of *Mariseus Magnas*, C. B. Clarke.

Type locality:—Mile 50, Jinja-Tororo Rd., Uganda.

Other records:—Roots of *Sporobolus phillippi* (Compositae), Bukoba, Tanganyika Territory.

This species is named after Dr. A. D. Imms, F.R.S., in grateful recognition of the facilities he has accorded me to carry out this and other work.

Genus *Ripersia*, Sign.

Ripersia inaequalis, sp. nov. (fig. 7).

Young adult females almost circular in outline; adults somewhat more elongate, dorsally highly convex, flattened ventrally; dorsally the waxy pattern gives the insect a speckled appearance; there are no tassels; ovisac small; ground-colour pale yellow. With five pairs of cerarii situated on the last five abdominal segments; each cerarius furnished with a long and a short spine; this inequality in size of the cerarian spines varies in amount but is always present; about five or six triangular

pores aggregated around each cerarius. Circular multilocular pores absent; triangular pores not very numerous; a few circular pores present in the thoracic region. Body setae stout and without much variation in length. Anterior and posterior dorsal ostioles small but distinct, ventral cicatrice not detected. Antennae six-segmented in the following proportions: (1) 12, (2) 12, (3) 8, (4) 8, (5) 11, (6) 27. Eyes small, circular, and not pigmented. Rostrum dimerous, distal segment about twice length of proximal. A few scattered translucent pores occur on the hind femora and tibiae; ungual digitules somewhat longer than claw and minutely knobbed; tarsals absent. Legs with segments in the following proportions:—

		Trochanter	Femur	Tibia	Tarsus	Claw
Fore limb	...	18	36	23	22	10
Mid limb	...	18	35	25	23	10
Hind limb	...	18	40	33	25	10

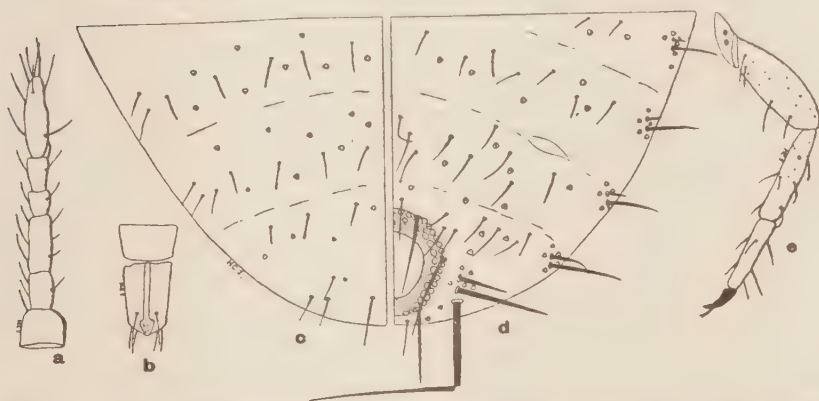


Fig. 7. *Rippersia inaequalis*, sp. n.: a, antenna ($\times 19$); b, rostrum ($\times 19$); c, posterior abdominal segments, venter (\times about 67); d, posterior abdominal segments, dorsum (\times about 67); e, posterior limb ($\times 19$).

Anal lobes undeveloped; caudal setae long and stout; anal ring setae very short and disproportionately stout, anal ring composed of two concentric rings of beaded cells.

Length 1.80–2.07 mm.; breadth 1.39–1.90 mm.

Type host:—Roots of *Sporobolus phillippi* (Compositae).

Type locality:—Samuru River Bridge, Nairobi-Thika Rd., Kenya.

Rippersia glandulosa, sp. nov. (fig. 8).

The adult female broadly ovate in outline, covered with an even thick coat of white wax; anal tassels only present; ground-colour pale yellow. With four pairs of cerarii, each cerarius with a pair of spines surrounded by a small cluster of triangular pores; the anal lobe cerarii may be slightly larger than the other cerarii, or the penultimate cerarii may be of equal size, or there may be little difference in the size of all four pairs of cerarii. Triangular pores numerous; circular multilocular pores few in number and confined to the posterior ventral region of abdomen; a number of irregularly circular orifices of large cylindrical ducts open on to the

derm ; a few small tubular ducts also present. Body setae numerous and long, and specially prevalent along the margins and in the median dorsal region of the derm. Anterior and posterior dorsal ostioles large and distinct ; the posterior pair somewhat the larger ; a single medio-ventral cicatrice occurs with narrow transverse orifice and thickened labiae which show a brownish stain.

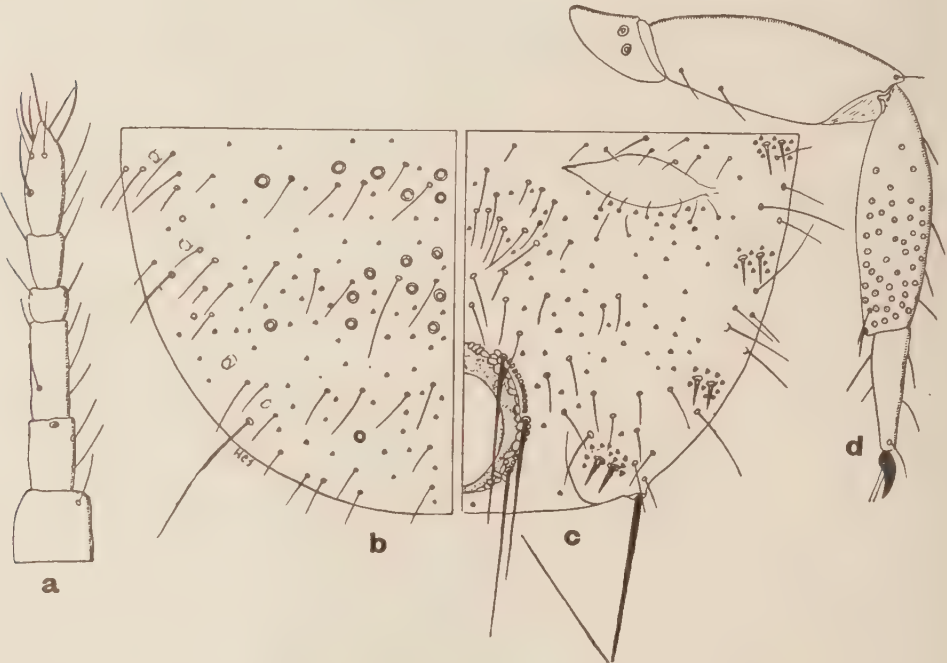


Fig. 8. *Ripersia glandulosa*, sp. n. : **a**, antenna ($\times 28.5$) ; **b**, posterior segments of abdomen, venter ($\times 75$) ; **c**, posterior segments of abdomen, dorsum ($\times 75$) ; **d**, posterior limb ($\times 28.5$).

Antennae six-jointed, with the segments arranged in the following proportions : (1) 15, (2) 15, (3) 24, (4) 7, (5) 11, (6) 24 ; four crassate setae arise from the terminal segment and a spine-like seta is situated at the apex. Eyes clearly defined. Rostrum a little longer than broad, dimerous, second segment the longer. Legs stout and fully formed ; tibiae of posterior limbs dilated and bearing on their outer aspect a number of relatively large circular pores ; ungual digitules slightly longer than claw and not knobbed ; tarsals not so long as claw, and also non-capitate. The segments of the legs in the following proportions :—

			Trochanter	Femur	Tibia	Tarsus	Claw
Fore limb	...		23	48	34	24	9
Mid limb	...		23	48	33	22	9
Hind limb	...		25	55	52	25	9

Posterior spiracles slightly larger than the anterior ones. Paranal lobe setae stouter and about twice as long as anal ring setae.

Length of body 1.56–1.83 mm.; breadth 0.97–1.33 mm.

With regard to this species, Mr. Green states *in litt.* that the numerous large tibial pores constitute a very remarkable character and differentiate this species from any *Ripersia* known to him. If other species with similar characteristics be found, it would justify the erection of a new genus.

Type host :—Roots of *Bidens pilosa*, L. (Compositae).

Type locality :—Nr. Outspan Hotel, Nyeri, Kenya Colony.

Other records :—Roots of *Conyza Volkensii*, O. Hoff (Compositae), nr. Tumu Tumu Mission, Nyeri; roots of *Pennisetum clandestinum* (Gramineae), Gura River Bridge, nr. Nyeri.

***Ripersia hypoestis*, sp. nov. (fig. 9).**

Adult female broadly ovate, with a thin covering of white wax; short anal tassels only; ovisac not seen; ground-colour pale yellow. With only one pair of cerarii situated on the anal lobes; each cerarius composed of a pair of conical spines with two or three auxiliary setae surrounded by an aggregation of triangular pores; triangular pores numerous all over derm; multilocular pores confined to posterior

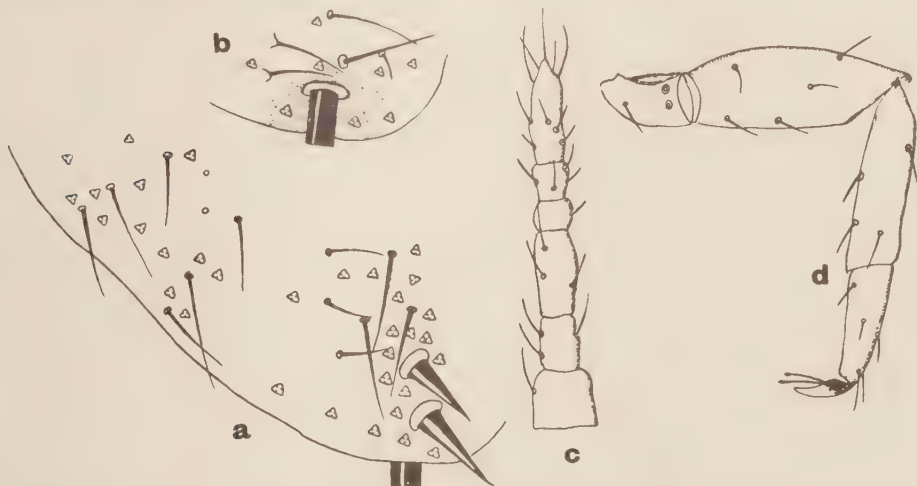


Fig. 9. *Ripersia hypoestis*, sp. n.: a, anal lobe cerarius ($\times 75$); b, anal lobe, ventral aspect ($\times 75$); c, antenna ($\times 57$); d, hindleg ($\times 57$).

ventral region; tubular ducts also present. Anterior and posterior dorsal ostioles and ventral cicatrice present. Antennae six-segmented in the following proportions: (1) 13, (2) 12, (3) 15, (4) 7, (5) 8, (6) 22; eyes small and very protuberant; rostrum dimerous and markedly elongate. Legs normal; ungual digitules slightly longer than claw and knobbed; tarsals more setiform and not knobbed; segments of the legs in the following proportions :—

	Trochanter	Femur	Tibia	Tarsus
Fore limb ...	19	35	29	20
Mid limb ...	19	36	32	21
Hind limb ...	21	40	42	22

Anal lobes small ; anal lobe setae about twice the length of anal ring setae.

Length of body 1.80–2.30 mm. ; breadth 1.60–1.80 mm.

Type host :—Roots of *Hypoestis verticillaris* (Acanthaceae).

Type locality :—Muringato River, Nyeri, Kenya Colony.

Other records : —*Themeda triandra*, Forsk. (Gramineae), Muringato River, Nyeri.

***Ripersia rotundata*, sp. nov. (fig. 10).**

Adult female round and plump ; waxy coating sparse ; no tassels ; ovisac yellowish and voluminous ; body content deep yellow with no true cerarii. In the posterior region are pairs of elongate spiniform setae arranged at the segmental intervals along the margin and without aggregations of pores around their bases ; anal lobes undeveloped ; body setae short and sparse ; caudal setae only slightly longer than anal ring setae. Triangular pores somewhat sparsely distributed ; circular multilocular pores confined to posterior ventral region of abdomen ; anterior and posterior dorsal ostioles small but well defined ; lips rather heavily chitinised ; ventral cicatrice not detected. Antennae relatively short, with six segments arranged in the following proportions (1) 8, (2) 9, (3) 5, (4) 5, (5) 6, (6) 16 ; bases of antennae noticeably closely approximated ; eyes present ; rostrum dimerous. Legs relatively short robust and spiny ; the segments of the limbs arranged in the following proportions :—

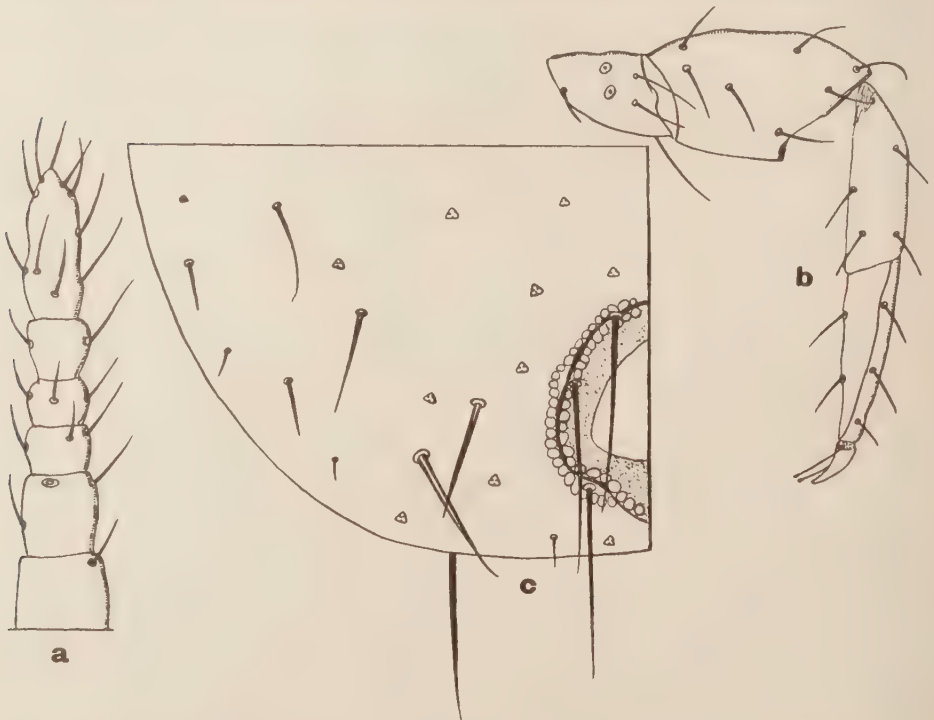


Fig. 10. *Ripersia rotundata*, sp. n. : **a**, antenna ($\times 57$) ; **b**, leg ($\times 57$) ; **c**, left half of posterior region of abdomen, dorsal aspect ($\times 75$).

	Trochanter	Femur	Tibia	Tarsus
Fore limb ...	15	26	18	19
Mid limb ...	15	26	20	20
Hind limb ...	15	24	20	18

Ungual digitules longer than claw and knobbed ; tarsals absent.

Length of body 1.50–3.40 mm. ; breadth 2.10–2.70 mm.

Type host :—Roots of *Digitaria abyssinica*, St. (Gramineae).

Type locality :—Kiamwere, Nyeri, Kenya Colony.

***Ripersia nuda*, sp. nov. (fig. 11).**

Adult female dusted with white wax ; no tassels ; body content yellow ; ovisac not seen. Without true cerarii ; the three posterior segments of the abdomen bear pairs of elongate spines without aggregations of pores around their bases ; anal ring normal and consisting of double rings of pores of the beaded type ; anal ring setae stout and shorter than paranal lobe setae ; derm setae stout and very scanty.

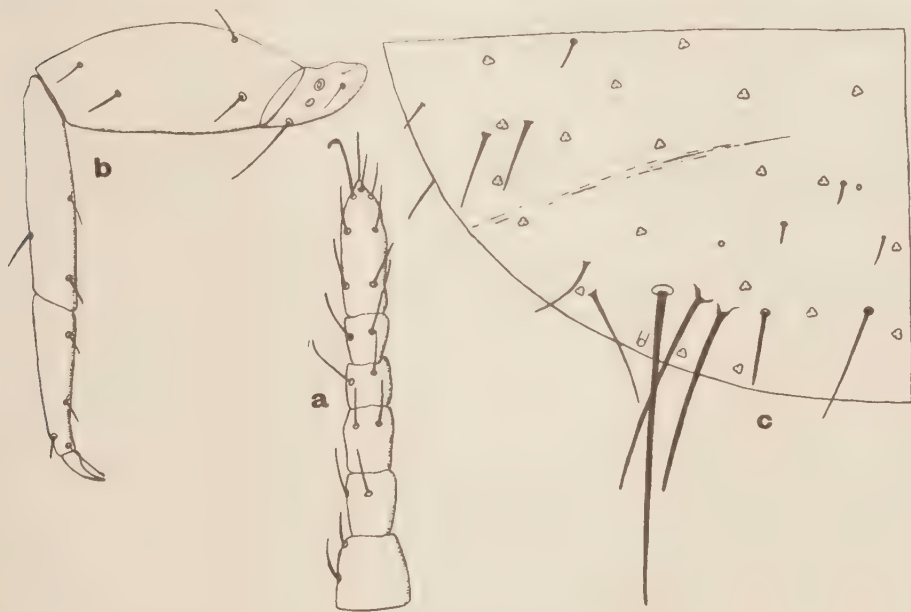


Fig. 11. *Ripersia nuda*, sp. n. : a, antenna ($\times 57$) ; b, hindleg ($\times 57$) ; c, dorsal aspect of the posterior extremity of the abdomen, left side ($\times 65$).

Triangular pores sparsely distributed ; multilocular pores absent ; anterior and posterior dorsal ostioles small and distinct ; ventral cicatrice not present in the specimens examined. Eyes protuberant and relatively small ; rostrum dimerous and robust ; rostral loop short. Antennae somewhat geniculate ; relatively short and six-segmented in the following proportions : (1) 8, (2) 7, (3) 7, (4) 5, (5) 5, (6) 14. Legs relatively short and the segments are arranged in the following proportions :—

		Trochanter	Femur	Tibia	Tarsus
Fore limb ...	...	13	25	20	15
Mid limb ...	...	14	25	21	13
Hind limb ...	...	13	26	25	16

Tarsal digitules short and not knobbed ; unguals extending to extremities of claws and knobbed.

Well developed embryos occur within the body of the female ; antennae of first instar larvae six-segmented.

Length 2·00–2·20 mm. ; breadth (under compression) 1·5–2·00 mm.

Type host :—Roots of *Setaria sphacelata* (Clarke).

Type locality :—Masaka, Uganda.

The types of the above species have been deposited in the British Museum.

THE CHALCIDOID PARASITES OF LAC-INSECTS.

By Ch. FERRIÈRE, D.Sc.,

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For the biological study of *Tachardia lacca*, Kerr, it is of importance to have, so far as possible, a complete knowledge of all the insects that live in relation with it—predators* and parasites of the Coccid, parasites of the predators and hyperparasites. This biological complex begins to be better known, owing to the studies of several entomologists in India, especially at the Indian Lac Research Institute at Namkum.

But the taxonomic knowledge of these parasites and hyperparasites is also of importance, and much confusion still prevails in the names and identity of many of the Hymenoptera. It is our intention in the following pages to try to clear up the identity of the parasites belonging to the CHALCIDOIDEA, which are the most important and the least known.

The material studied below has been sent to the Imperial Institute of Entomology mainly by the Indian Lac Research Institute, but other smaller collections have been received from other parts of India, as well as from Ceylon and the Malay States. Cameron's types and other specimens in the British Museum have also been re-examined. Furthermore Dr. A. B. Gahan, of the United States National Museum, who has had the opportunity of studying several species sent by A. Mahdihassan, has been kind enough to let me have some of these species and to give me valuable information for which I am glad to thank him here.

We give below a list of all the Hymenoptera known to us to occur on lac insects, but, as stated, only the Chalcids will be studied here.

I. Parasites of *Tachardia lacca*.

EUPELMIDAE.	<i>Eupelmus tachardiae</i> , How.	
ENCYRTIDAE.	<i>Tachardiaephagus tachardiae</i> , How. and var. <i>somervilli</i> , Mahd. <i>Erencyrtus dewitzi</i> , Mahd. <i>Parechthrodryinus clavicornis</i> , Cam. <i>Atropates hautefeuillei</i> , Mahd.	
APHELINIDAE.	<i>Coccophagus tschirchii</i> , Mahd. <i>Marietta javensis</i> , How.	
EULOPHIDAE.	<i>Tetrastichus purpureus</i> , How.	/Cam.

II. Parasites of *Eublemma* spp.

BRACONIDAE.	<i>Bracon greeni</i> , Ashm. XVI, 259-4 (= <i>Bracon tachardiae</i> , Cam.) <i>Aphrastobracon flavipennis</i> , Ashm.	
CHALCIDIDAE.	<i>Brachymeria tachardiae</i> , Cam.	
ELASMIDAE.	<i>Elasmus claripennis</i> , Cam.	

* The most important are the predacious caterpillars of the Noctuid moth, *Eublemma amabilis*, Moore, and of the Tineid, *Holcocera pulverea*, Meyr.

III. Parasites of *Holcocera pulvereae*, Meyr.

- BRACONIDAE. *Phanerotoma buchneri*, Fahr.¹
Agathis bischoffi, Fahr.¹
Apanteles tachardiae, Cam.²
Apanteles fakrulahajiae, Mahd.²
- CHALCIDIDAE. *Brachymeria tachardiae*, Cam.
- EURYTOMIDAE. *Eurytoma pallidiscapus*, Cam.

IV. Bred from Lac, Host unknown.

- ICHNEUMONIDAE. *Pristomerus laccae*, Cushm.³
- BRACONIDAE. *Holcobracon coxalis*, Turner⁴
Blacus tachardiae, Cam.⁵
- ENCYRTIDAE. *Anicetus dodonia*, sp. nov.
Proleurocerus fulgoridis, sp. nov.

***Brachymeria tachardiae*, Cam.**

Chalcis tachardiae, Cameron, Ind. Forest Rec. 4 pt. 2, 1913, p. 3.

♀. Black; tegulae, tip of femora, base and tip of tibiae and all tarsi yellow; the anterior tibiae are entirely yellow in front.

Head seen from in front a little broader than long; cheeks with a fine carina from the mouth to the base of the eyes and continued along the hind margin of the eyes. Antennal grooves rather deep, carinated along the lateral margins, which are almost parallel, converging slightly toward the anterior ocellus. Vertex and frons finely reticulated. Lateral ocelli much nearer the eye-margin than their own diameter. Antennae with the scape elongate, reaching almost to the anterior ocellus, as long as the pedicel with the three first funicle joints together; pedicel small, rounded; funicle broader, the 1st joint slightly longer than broad, the following joints quadrate, the 6th and 7th slightly broader than long; club a little shorter than the two preceding joints together. Thorax more strongly reticulated than the vertex, the spaces between the punctuation finely shagreened, dull, except in the middle of the scutellum where they are smooth. Hind margin of scutellum rounded, not emarginate in the middle. Propodeon smooth, areolated; the central area narrow, elongate, divided by a weak transverse carina; lateral areae large and more or less rectangular. Wings hyaline; the length of the submarginal, marginal, stigmal and postmarginal veins is in the proportion 65, 28, 5, 10. Hind femora ovate, as broad as 0.56 of the length, finely punctate, almost smooth. Abdomen as long as the thorax, pointed at tip, the tergites smooth above, the last two only slightly shagreened. Ovipositor scarcely protruding.

♂. Similar to ♀. Abdomen shorter than the thorax and rounded behind.

Length: ♀ 3.0-3.5 mm., ♂ 2.2-3.3 mm.

Redescribed from a series of 6 females and 19 males received from the Indian Lac Research Institute, Namkum.

Host. Endoparasite on pupae of *Holcocera pulvereae*, Meyr., and *Eublemma amabilis*, Moore.

¹ Fahringer, Z. angew. Ent., xix, 1932, pp. 144-145.

² Wilkinson, Bull. Ent. Res., xix, 1928, pp. 119 & 135. A new series of *A. fakrulahajiae* received from the Ind. Lac Res. Inst. has been recognised by Mr. Wilkinson as a good species; *Apanteles rufulus*, Wilk. is a synonym (see Wilkinson, Stylops, iv, 1935, p. 72).

³ Cushman, Ind. Forest Rec., xx, 1934, p. 6.

⁴ Ann. Mag. Nat. Hist. (9) x, 1922, p. 274. One female received from Lyallpur, Punjab, labelled "Lac on Fig."

⁵ = *Ectadiophatnus tachardiae*, Cam., after Gahan *i.l.*

Compared with the type (♀) and 4 cotypes in the British Museum, all more or less damaged. Since first described by Cameron, it has been recognised and mentioned by Imms & Chatterjee (1915), Mahdihassan (1925 & 1929) and Glover (1930). It can be recognised from other Indian *Brachymeria* by its small size, the pointed and smooth abdomen, the rounded scutellum and the length of the postmarginal vein, which is only about twice the length of the stigmal.

Another species, *Brachymeria euplocae*, Westw., has been received from Lyallpur, Punjab, labelled "from lac." It is a common species all over the Indo-Malayan region, being a parasite of several Lepidoptera and probably only an occasional parasite of the pupae of predacious species on lac. It is much larger than *B. tachardiæ* and can be distinguished by the yellow hind tibiae, which are only black or brown at the base and along the inside, the punctate base of the second abdominal segment, and the scutellum excavated at the hind margin.

Eurytoma pallidiscapus, Cam.

Eurytoma pallidiscapus, Cameron, Ind. For. Rec. 4 pt. 2, 1913, p. 8.

♂♀. Body black; antennae with the scape and pedicel yellow, the flagellum black; legs yellow, coxae black, front and median femora broadly black above, except at tip, hind femora black, except at base and tip; the base and tip of tibiae and the tarsi lighter yellow; tegulae and wing nervature light yellow; end of valvi brownish.

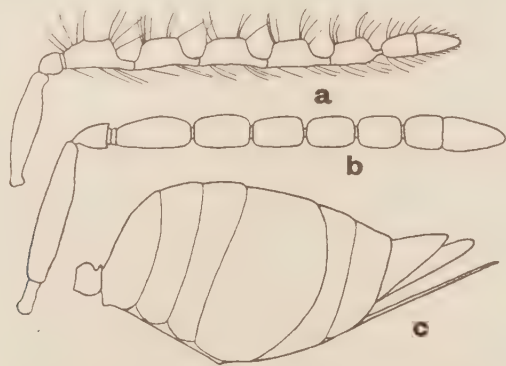


Fig. 1. *Eurytoma pallidiscapus*, Cam.: a, antenna ♂; b, antenna ♀; c, abdomen.

Head finely reticulated, the punctation shallow; face and cheeks covered with white ciliae. Clypeus smooth. Antennal furrow with the margins carinated, as broad as its distance from the eye, reaching above the front ocellus. Ocelli in a low triangle, lateral ocelli as far distant from the eye-margin as their own diameter. Antennae inserted in the middle of the face; scape narrow, reaching almost the front ocellus; pedicel short, scarcely longer than broad; funicle with 5 joints, the 1st more than twice as long as broad, 2nd shorter, but still almost twice as long as broad, the following joints gradually shorter, but all longer than broad; club with 2 joints, about as long as two preceding joints together. Thorax more strongly reticulated than the head, dull; propleura finely punctate; mesopleura smooth anteriorly, punctate and irregularly striate in the middle, smooth and more strongly striate posteriorly; propodeon reticulated on the sides, the median concave portion punctate, with two median carinae converging behind; the central area thus formed elongate and regularly reticulated. Wings broad, not reaching to the tip of the abdomen; marginal vein as long as the postmarginal and about 1.5 times as long as the stigmal. Hind coxae punctate, dull, above. Abdomen quite smooth; petiole

very short, broader than long; 2nd segment short, 3rd and 4th segments of the same length; 5th twice as long as the 4th, 6th and 7th very short, transverse, 8th a little longer and narrower, triangular. Ovipositor scarcely protruding.

♂ similar; femora more blackish, only yellow at tip; antennae with the scape short, pedicel rounded, the 5 funicle joints broadened in the middle, with two whorls of hairs, and ending in a narrow petiole; 1st joint a little shorter than the scape, the following joints shorter, but all longer than broad; club with two joints not separated by a petiole. Abdomen shorter than the thorax, seen from the side rounded, with the petiole a little longer than the hind coxae.

Length: ♀ 2.8-3.8 mm.; ♂ 1.5-3.0 mm.

Redescribed from a series of 15 females and 9 males from Namkum.

Host. *Holcocera pulvereae*, Meyr.

We have compared these specimens with Cameron's type in the British Museum. The type, a female, is partly broken and without abdomen, which explains perhaps why no mention of it is made in the description. Cameron mentions on the mesonotum "a longish triangular, smooth and shining space above." We have not been able to see anything like this, neither on the type, where the thorax is pierced by a thick pin, nor on the specimens from Namkum. The length of the type is given as 2 mm.; this is the length of head and thorax only, with the abdomen it would have been about 3.5 mm.

Imms & Chatterjee (1915) mention this species as a rare parasite of *Holcocera*. Mahdihassan (1929) says that it is common at Mysore, but rare in the north of India.

***Eupelmus tachardiae*, How.**

Anastatus tachardiae, Howard, Proc. U.S. Nat. Mus. **18** 1896, p. 641.

Brasema annulicaudis, Cameron, Ind. For. Rec. **4** pt. 2, 1913, p. 8.

♀. Black with green and brassy reflections, and more or less purple, especially on the face, vertex and scutellum; abdomen violaceous with the base shining green; antennae black with the scape yellow, and green reflections on the pedicel and sometimes also the first funicle joints; legs reddish yellow, the coxae black with metallic reflections, the front and hind femora brownish black except at tip, the anterior tibiae brown in the middle above and the hind tibiae also more or less brown in the middle; valvae narrowly black at base, dark brown at tip, with a broad yellow ring in the middle.

Head finely shagreened with weak transverse striation behind the ocelli; margin of occiput carinate. Antennal furrows rather deep, punctate, the top finely striate. Ocelli forming a low triangle, the front ocellus as far from the antennal furrow as from the margins of the eyes, lateral ocelli at a distance from the eyes equal to their own diameter. Antennae inserted a little below the lower level of the eyes; scape cylindrical, not reaching to the front ocellus; pedicel elongate, twice as long as broad; annellus small, transverse; 1st funicle joint about as long as the pedicel, the following joints gradually shorter and broader, the 6th subquadrate, the 7th a little broader than long; club as long as 3 preceding joints together. Thorax finely shagreened, dull, scutellum slightly striate; the parapsidal furrows meet in the middle of the mesonotum and are continued behind by a weak central furrow. Axillae distinctly separated in the middle. Propodeon very short, transverse. Wings large, reaching beyond the tip of the abdomen; marginal vein a little longer than the submarginal narrow; stigmal vein as long as one-fourth of the marginal; postmarginal vein as long as the stigmal. Fore legs with the femora not much thickened, the tibia shorter than the femora; spur of middle tibiae as long as the metatarsus, which is thick and short and with black spines below. Abdomen as

long as or a little shorter than the thorax and not broader, finely shagreened above and rounded behind. Ovipositor as long as 0.4 of the abdomen.

5. Smaller, black with greenish reflections; antennae entirely black, greenish on scape and pedicel; legs black, only the anterior tibiae below and at tip, the middle and hind tibiae at tip, and the tarsi at base, yellow. Scape broadened in

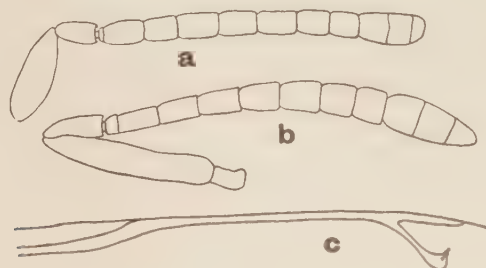


Fig. 2. *Eupelmus tachardiae*, How.: a, antenna ♂; b, antenna ♀; c, wing neurulation.

the middle; pedicel a little longer than broad; the 7 funicle joints subequal in length, the last a little shorter; club as long as 2 preceding joints together. Thorax normal, mesonotum convex with the parapsidal furrows complete; scutellum almost as long as the mesonotum; propodeon short. Wings with the marginal vein about four times as long as the stigmal. Legs normal. Abdomen shorter and narrower than the thorax, slightly broadened behind, triangular.

Length: ♀ 2.5-3.3 mm.; ♂ 1.3-2.3 mm.

Redescribed from a series of 27 females and 8 males from Namkum.

Host. *Tachardia lacca*, Kerr.

We have been able to compare these specimens with the type and cotypes of Cameron's *Brasema annulicaudis* in the British Museum, from Dehra Dun. There are 4 females, one of which is very small, only 1.8 mm. in length.

Other specimens received by the Imperial Institute of Entomology include: INDIA: Punjab, Lyallpur, 1931 & 1932, "from lac," 2 ♀♀, both very small, 1.5 & 1.8 mm. in length. CEYLON: Wattegama, 1923 (Dr. J. C. Hutson), "ex *Tachardia albizziae*," 2 ♂♂, 1.1 & 1.9 mm. in length. SIAM: 1931, "ex brood lac," 1 ♂, length 2.2 mm.

Howard described his *Anastatus tachardiae* from a single male, reared by Mr. E. E. Green from *Tachardia albizziae* in Ceylon. Cameron knew only the female of his *Brasema annulicaudis*. The series of both sexes bred at Namkum shows without any doubt that both belong to the same species and that they must be included in the genus *Eupelmus*. The males obtained from Ceylon agree with Howard's description and with the other males bred from *T. lacca*. Dr. Gahan has seen specimens bred by Mahdihassan in India and tells us that they agree with Howard's type. As can be seen, this species varies much in size and, as is often the case, the smaller specimens have darker legs than the larger ones.

This species has been known by most authors as *Brasema annulicaudis*. Imms & Chatterjee (1915) mention it as a parasite of *Eublemma amabilis* and *Holcocera pulverea*. Mahdihassan (1923 & 1925) also considers that it is a parasite of *Eublemma amabilis*; he says that it had already been described by Gernet in 1863 under the name of *Pteromalus* sp. Glover (1930) has observed that it can be either a primary parasite of *Tachardia lacca* or a hyperparasite. Like several European *Eupelmus* it has probably several hosts and may not be specially related to the lac insects.

Tachardiaephagus tachardiae, How.

Encyrtus tachardiae, Howard, Proc. U.S. Nat. Mus. **18** 1896, p. 641.

Tachardiaephagus thoracicus, Ashmead, Mem. Carnegie Mus. **1** no. 4, 1904, p. 303.

Lissencyrtus troupi, Cameron, Ind. For. Rec. **4** 1913, p. 8.

This is a well-known parasite of *Tachardia lacca*, which has been described by several authors, figured in colours by Imms & Chatterjee (1915), and mentioned already by us in 1928. We do not think it necessary to redescribe it here, but include a figure of the antennae of the female and male in order to show the difference from the antennae of *Erencyrtus dewitzi*, Mahd., which is very similar in coloration.

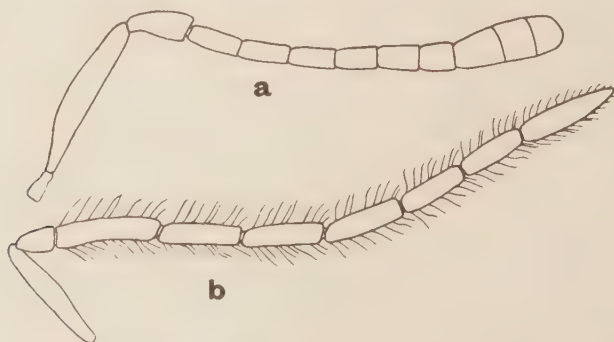


Fig. 3. *Tachardiaephagus tachardiae*, How.: **a**, antenna ♀; **b**, antenna ♂.

Since our last note on that species, we have seen the following specimens: INDIA: Namkum (*P. M. Glover*), several ♀ and ♂, labelled "ex *Laccifer lacca*"; Punjab, Lyallpur (*Afzal Husain*), 1 ♀, "associated with lac." CEYLON: Wattegama (*J. C. Hutson*), 1 ♀ 1 ♂, "ex *Tachardia albizziae*." MALAYA: Kedah (*G. H. Corbett*), 2 ♀ 3 ♂, "from Lac incrustations"; Rawang and Kuala Selangor (*N. C. E. Miller*), 2 ♀, "ex *Tachardia* sp."; Serdang (*N. C. E. Miller*), 13 ♀ 1 ♂, "ex *Coccidae*."

Many specimens, males and females, from India (Namkum) and all specimens from Malaya (Serdang) differ from the typical form by having the head entirely reddish yellow like the thorax. Mahdihassan (1923) mentions this form under the name of *Lissencyrtus somervilli*, with the following words: "On *Shorea* we meet with a new species allied to *Lissencyrtus troupi*. It is easily distinguished from the last named by its greenish yellow eyes and an entirely orange yellow head instead of dark eyes and a metallic coloured head . . ." We have not been able to find any morphological differences between these two forms and we propose to call the form with orange yellow heads *Tachardiaephagus tachardiae* var. *somervilli* Mahd. We have found intermediate forms in two females from Malaya (Rawang and Kuala Selangor Road), in which the head has the vertex, the temples and cheeks dark green like *tachardiae*, and the face and inner margin of the eyes reddish, as in *somervilli*.

T. tachardiae and its variety vary much in size; some females are only 1.2 mm. long, while others reach a length of 2.5 mm.

Erencyrtus dewitzi, Mahd.

Erencyrtus dewitzi, Mahdihassan, J. Sci. Ass. Vizianagaram **1** 1923, p. 70.

♀♂. Head green with purple reflections, especially between the antennal furrows; antennae yellow, slightly brownish on the upper sides of pedicel and funicle joints; thorax orange yellow, with the pronotum brownish in front and

a green oval spot covering the posterior part of the pronotum and the anterior third of the mesonotum; propodeon and metanotum brownish on the sides; abdomen brown, more or less yellowish at base. Legs yellow, with a small brown spot on the middle and hind tibiae near the base. Wings hyaline. The male has the head darker and the mesonotum entirely greenish above.

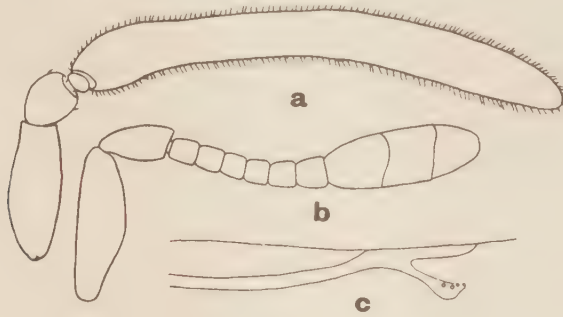


Fig. 4. *Evencyrtus dewitzi*, Mahd.: a, antenna ♂; b, antenna ♀; c, wing neurulation.

♀. Head transverse, as broad as the thorax; vertex broad, the lateral ocelli situated very near the margin of the eyes, which are large and rounded. Vertex and face granulose, dull, with a few scattered, larger punctures. Antennal furrows converging and uniting before the front ocellus. Cheeks large, rounded, with a short vertical furrow below the eyes. Mandibles with 3 teeth. Antennae inserted just above the clypeus; scape a little broadened in the middle, not reaching to the front ocellus; pedicel twice as long as broad; the first 5 funicle joints small, subquadrate, narrower than the pedicel, 6th joint a little larger, as broad as the pedicel and almost quadrate; club oval, broader, almost as long as the funicle. Thorax short, oval, finely shagreened; mesonotum broader than long; axillae triangular, their inner angles touching in the middle; scutellum large, almost as long as the mesonotum, very convex and rounded behind, covering the middle of the propodeon, which is very short and transverse. Wings large, reaching beyond the tip of the abdomen; submarginal vein reaching almost the middle of the front margin, marginal vein punctiform or scarcely longer than broad, stigmal and postmarginal veins subequal in length; below the stigma an oblique glabrous line, before which the discal ciliae are a little stronger. Legs normal; spurs of middle tibiae almost as long as the metatarsus; hind femora somewhat thickened. Abdomen shortly oval, not or scarcely longer than the thorax. Ovipositor not protruding.

♂. Similar to the female, from which it differs only by the form of the antennae; these are formed by the scape, about thrice as long as broad in the middle, the short pedicel as long as broad, two small funicle joints, transverse, not easily seen, and a club formed by one very elongate joint, 3 times or more as long as the scape, covered with short hairs.

Length: ♀ 0.8–1.4 mm.; ♂ 0.9–1 mm.

Redescribed from a series of many females and 2 males from India, Namkum, 1933 (*P. Glover*).

Other specimens were received from: Namkum, 4 ♀♀ (*P. Glover*); Bangalore, 1 ♀ 1 ♂ (*Mahdihassan*); Lyallpur, Punjab, 2 ♀♀ (*Afzal Husain*).

Mahdihassan's specimens were sent to Dr. Gahan at the U.S. National Museum, who recognised them as a good genus and species, and were presented by him to the British Museum. The males seem very rare; among more than 100 females from Namkum, only 2 males could be found.

This species had never been described. Mahdihassan (1923) mentioned it only in the following words: "During the drier portions of the year *Ficus* lac is attacked by a yellow insect which appears to be its main Chalcid enemy. It is related to *Lissencyrtus*, Cam. The male of this new Chalcid has a very long club as in the antenna of the Apheline genus *Eretmocerus*. For this reason I propose naming the new genus *Erencyrtus*. In memory of the great insect physiologist, the late Prof. Dewitz, I propose calling the insect *E. dewitzii*. This insect also attacks lac on *Z. izyphus*] *jujuba* in Pakur and in Pusa. Lac insects on *F. bengalensis* in Hyderabad suffer most from the attack of this Chalcid. This insect has never been reared from *Shorea* lac." In 1925 he adds only that Roxburg had already mentioned a parasite of *T. lacca* with a "colour between the eyes beautiful shining green"; this, adds Mahdihassan, "is particularly applicable to *Erencyrtus dewitzii*. From specimens of *Metatachardia conchiferata* the only Chalcids reared were *E. dewitzii*. The genus *Erencyrtus* is more primitive than *Lissencyrtus*; the male has a long terminal joint in the antenna like that of the Apheline genus *Eretmocerus*, and would appear to be intermediate between Aphelines and Encyrtines."

The curious form of the antennae of the male is not only found in *Eretmocerus* but also in the Encyrtid genus *Habrolepis*, Forst. But the genus *Erencyrtus* is not related to *Habrolepis*, the females differing by the form of the head and antennae, the absence of appendages on the scutellum and the hyaline wings.

***Parechthrodryinus clavicornis*, Cam.**

Copidosoma clavicornis, Cameron, Ind. For. Rec., 4 1913, pt. 2, p. 11.

♂. Body black with metallic reflections, bluish green on the head, especially on the cheeks and temples, dark green or more or less black on the mesonotum, cupreous on the scutellum and aeneous on the abdomen, with the first segment shining green. Antennae yellow, the pedicel and the first three funicle joints more or less brown above, the club dark brown. Antennae of male entirely yellow, only the pedicel slightly brown above. Legs yellow, the coxae and sometimes the hind femora above brown. Wings hyaline.

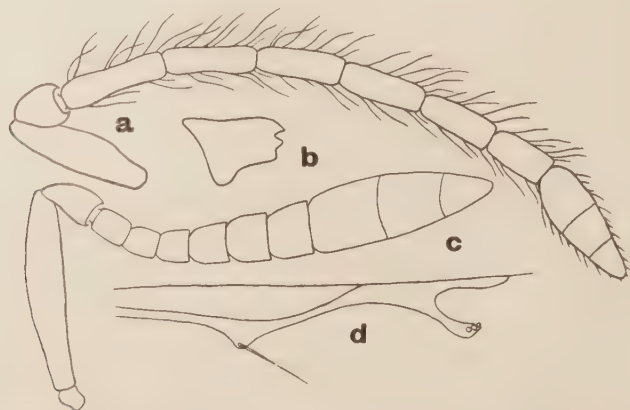


Fig. 5. *Parechthrodryinus clavicornis*, Cam.: a, antenna ♂; b, mandible ♀; c, antenna ♀; d, wing neuration.

♀. Head transverse, eyes large, vertex and frons narrow; ocelli forming a high triangle, the lateral ocelli very near the eye-margins and nearer to each other than to the front ocellus; antennal furrows short, converging and meeting together. Cheeks

almost as long as the diameter of an eye. Mandibles with 3 teeth, the lowest truncate. Antennae inserted a little above the clypeus; scape rather short, not nearly reaching the front ocellus, pedicel about twice as long as broad, 1st funicle joint small, rounded or subquadrate, the following joints gradually broader, the 6th a little broader than long; club with 3 joints, about as long as 5 preceding joints together. Mesonotum finely shagreened, almost smooth, with sparse and shallow punctation. Scutellum finely reticulated, the lateral margins converging behind, where it is rounded and convex; axillae triangular, meeting in the middle. Propodeon very short in the middle, covered by the tip of the scutellum. Wings large, reaching beyond the tip of the abdomen; submarginal vein with a row of 7 to 9 long hairs and a small triangular expansion just before it curves up; marginal vein about twice as long as broad; stigmal vein narrow and about as long as the marginal, the knob small and oval; postmarginal vein as long as the stigmal; discal ciliation small, with an oblique hairless line below the marginal vein. Abdomen as broad as the thorax at the base, pointed behind, the sensoria placed before the middle. Ovipositor slightly protruding, scarcely shorter than the spur of the middle tibiae.

♂. Similar to the female, from which it differs only by the form of the antennae; these are elongate, with the pedicel rounded, the 1st funicle joint about 4 times as long as broad, the following joints a little shorter, but all at least twice as long as broad and all covered with long hairs; club narrow, as long as two preceding joints together.

Length: ♀ 1.0–1.6 mm.; ♂ 0.9–1.3 mm.

Redescribed from a series of 22 females and 12 males from Namkum, 1933 (*P. Glover*).

Other specimens examined were all from India: Dehra Dun, 5 ♀, 1 ♂ (Cameron's type and cotypes); Bangalore, 1 ♀, 1924 (*Mahdihassan*); Lyallpur, Punjab, 1 ♀, 1932 (*Afzal Husain*).

To the original description of the species, Cameron added also a generic description, as "I am not quite certain if this species is a true *Copidosoma*." Imms & Chatterjee (1915) gave a figure of it. Mahdihassan (1925) confirms that it is a parasite of the Coccid and adds that it has been found in different localities but is nowhere common; he says that it is surely not a *Copidosoma*. Later, specimens sent to Dr. Gahan were referred by him (*in litt.*) to the genus *Parechthrodryinus*, Girault. This genus was founded by Girault (1916) for a Japanese species, *P. convexus*, Gir., reared from a Coccid on twigs of *Deguelia microphylla*. The short description of the genus is as follows:—"In my table to the earth's ectromine genera of Encyrtidae runs to *Echthrodryinus*, Perkins, but differs in that the postmarginal vein is half the length of the stigmal, the latter slightly longer than the marginal, which is twice longer than wide. The narrow frons is about three and a half times the diameter of the cephalic ocellus. Ovipositor exerted slightly, white at apex." Girault places this genus among the ECTROMINI; in reality it belongs to the ENCYRTINI, having three teeth on the mandibles.

Dr. Gahan has been able to compare *P. clavicornis*, Cam., and *P. convexus*, Gir., and sends me the following notes on them: "I am satisfied that they belong to the same genus. In fact I would not be surprised if they were the same species. Girault's types have had the heads removed and crushed on a slide, but the antennae and mandibles are intact and they appear to me to be almost exactly like those of *clavicornis*. The wing of *P. convexus* is also very poorly mounted on a slide and seems to show the triangular projection from the submarginal vein, although this appears less distinct than in the wing of *clavicornis*."

The triangular projection below the submarginal vein is also found in the genus *Protyndarichus*, Mercet (1922) (= *Tyndarichoides*, Mercet 1921, not Girault 1920). This genus is very closely related to *Parechthrodryinus*; but *Protyndarichus metallicus*,

Merc., from Spain, differs by its very short stigmal and postmarginal veins, the former being shorter than the marginal vein, and by a somewhat smaller antennal club.

***Atropates hautefeuillei*, Mahd.**

Microterys hautefeuillei, Mahdihassan, J. Sci. Ass. Vizianagaram, **2**, 1925, p. 65.

♀. Head and thorax orange yellow, slightly brownish on the mesonotum, where are some greenish reflections; scutellum more yellow; abdomen black, the apical half more or less yellowish brown above. Antennal scape yellow, with a black stripe along the ventral margin, pedicel yellow with a black spot above, 1st to 4th funicle joints and the club blackish, 5th and 6th funicle joints whitish. Legs orange yellow, the tibiae more yellowish; middle and hind tibiae each with two brown rings, front tibiae with only one brown ring near the base. Wings slightly infusate, the base and two oval spots, one below the marginal and the end of the submarginal veins, the other near the hind margin of the wing hyaline.

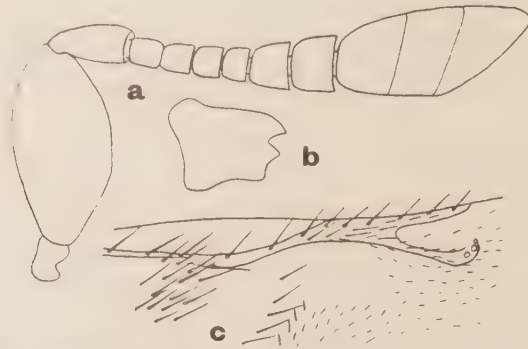


Fig. 6. *Atropates hautefeuillei*, Mahd.: a, antenna; b, mandible; c, wing neuration.

Head large, eyes rounded; vertex and frons as broad as one-third of the head; lateral ocelli situated near the eye margins, nearer to the front ocellus than to each other. Antennal furrows rather deep, the sides converging above, bordered by a sharp margin. Seen from in front the head is a little broader than long, with the cheeks rounded, as long as the diameter of an eye. Antennae inserted on the sides of the clypeus; scape flattened and broad, less than twice as long as broad; pedicel narrow, twice as long as broad; the first two funicle joints small, rounded, the following joints broadening gradually, all a little broader than long; club with 3 joints, broader than the funicle and about as long as 5 preceding joints together. Mesonotum finely shagreened, almost smooth, slightly broader than long; axillae narrow, their inner angles meeting in the middle; scutellum finely reticulate, dull, as long as the mesonotum. Propodeon very short in the middle, hidden under the tip of the scutellum. Wings large, reaching much beyond the end of the abdomen; submarginal vein narrow, marginal vein somewhat thickened, about twice as long as broad; stigmal vein narrow, not or scarcely longer than the marginal; postmarginal vein shorter than the stigmal; submarginal vein with 4 to 5 hairs, and under the curve with a brownish spot covered by several black hairs; a little farther on an oblique line of ciliae; all the rest of the base of the wing glabrous. Legs short, the femora and the end of the tibiae slightly broadened and compressed. Abdomen shorter than the thorax, not much pointed behind; ovipositor scarcely protruding.

♂. Body entirely black, with greenish reflections on head and thorax; face more shining green; antennae and legs entirely yellow, the pedicel and the tip of the flagellum slightly brownish; middle and hind tibiae with more or less distinct

brownish half-rings. Antennae elongate, scape short and slightly broadened in the middle; pedicel very short, not longer than broad; 1st funicle joint about twice as long as broad; the following joints thrice as long as broad, the last a little narrower and shorter than the 2nd; all funicle joints covered with long hairs; club indistinctly divided, shorter than the two preceding joints together. Head more transverse and vertex a little broader. Wings hyaline. For the rest, similar to the female.

Length: ♀♂ 1.2 mm.

India, Bangalore, 2 ♀♀ 1 ♂, 14. ii. 1924 (S. Mahdihassan).

This description has been made from specimens named *Microterys hautefeuilli* by Mahdihassan and sent by him to Washington. They may be considered as cotypes, although the type had never been described. 1 ♀ and 1 ♂ belong to the U.S. National Museum, 1 ♀ on a slide is deposited in the British Museum.

The only mention of this species given by Mahdihassan is:—"The female is yellow in appearance like *E. dewitzi*. The wings have smoky patches with streaks of pure white in them; the legs are striped across like those of *Aphycus punctipes*, Dalm. The male is brownish with wings less smoky. A full description is postponed for a future occasion." It seems to be rare and has, as Mahdihassan says, only been bred from *Tachardia chinensis*.

Dr. Gahan, who had examined these specimens, placed them in the genus *Atropates*, Howard. He had the kindness to send them to us for study accompanied by the following notes: "This species closely resembles a *Microterys* and in broad interpretation might be said to belong in that genus. The head of the female is thicker antero-posteriorly than in typical *Microterys*, the frons a little more prominent, the scrobal cavity deeper and more sharply limited, the thorax dorsally more convex, the stigmal vein a little shorter than the marginal (distinctly shorter than in typical *Microterys* which have a rather long stigmal vein). . . . In my opinion *M. hautefeuilli* agrees very well generically with *Atropates collinsii*, Howard, although a distinct species."

Two other Encyrtids were among the material of Lac insect parasites sent by Mahdihassan to Washington. They were labelled "*Cerapteroceris dodonia*, Mahd." and "*Cerapteroceris fulgorid*, Mahd." but had never been described or even mentioned in a paper. As they bear the same number and the same date as *Atropates hautefeuilli*, and may therefore be also related to *Tachardia lucca*, they were kindly sent to us by Dr. Gahan and are described hereunder.

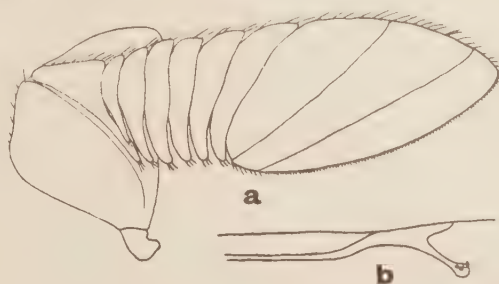


Fig. 7. *Anicetus dodonia*, sp. n.: a, antenna; b, wing neurulation.

Anicetus dodonia, sp. nov.

♀. Body orange yellow; face yellow, with two black lines coming from the middle of the cheeks and meeting between the antennae; antennae orange yellow, with a black line on the lower margin of the scape, club brownish; legs yellow, middle and hind tibiae each with two brown rings, the lower two-thirds of the hind metatarsi also brownish; abdomen brown at base.

Head transverse, oval, eyes large; ocelli forming a regular triangle, the lateral ocelli situated near the eye-margin; fronto-vertex as broad as 0.4 of its length; frons prominent, angulated, the face much reflexed; mandibles with 2 teeth, the upper a little longer than the lower. Antennae inserted on the sides of the face, very broad and flattened; scape triangular, as long as broad; pedicel small, elongate on one side, below; the 6 funicle joints short and very transverse, about 5 times as broad as long; club with 3 joints obliquely truncate, as long as the funicle and the pedicel together. Thorax finely shagreened, almost smooth, shining; mesonotum a little broader than long, with small sparse black ciliae; scutellum triangular, with small ciliae at base and 4 longer black hairs in pairs before the tip. Wings slightly infumate with the base and tip hyaline and a stronger infuscated band forming a half circle beyond the nervature across the wing just before the hyaline tip; marginal vein very short, about twice as long as broad; stigmal vein not longer than the marginal, a little longer than the postmarginal; base of wing glabrous, below the end of the submarginal vein and before the oblique hairless line, the ciliation is relatively long but sparse; beyond this line the ciliation is denser, somewhat longer and more black below the marginal and stigmal veins than in the middle of the wing. Middle tarsi short, the metatarsi as long as the 4 other joints together; spur of middle tibiae as long as the metatarsus. Abdomen a little shorter than the thorax, narrowed behind; ovipositor slightly longer than half the length of the abdomen.

Length: 1.3–1.8 mm.

INDIA: Bangalore, 2 females, 14.ii.1924 (S. Mahdihassan). Labelled "Roh. lot. 1783. *Cerapterocerus dodonia* Mahd. MS."

Anicetus ceylonensis, Howard, a parasite of *Vinsonia stellifera* in India and Ceylon, a related species, may be distinguished specially by the short ovipositor, which is "just showing" and by the wings "nearly uniformly cloudy." It is dark honey-yellow, with faint purplish lustre on the mesonotum, vertex and sides of the 1st abdominal segment.

A. chinensis, Girault, from China, is larger (2 mm.) and is deep orange in colour, with the disk of the abdomen and a broad line down the propodeon deep metallic purple. The marginal vein is thrice as long as wide and a little longer than the stigmal vein. The ovipositor is only "extruded a short distance."

A. annulatus, Timberlake, a parasite of *Eucalymnatus tessellatus* in Hawaii and of *Coccus* spp. in Japan is a small species (0.7–1.2 mm.), ochraceous in colour, with a transverse black band across the face, the propodeon blackish on each side of the middle and the abdomen black above with a bluish and greenish lustre. The hind tibiae have two black rings and the 1st joint and apex of the hind tarsi are also blackish. The ovipositor is scarcely protruding.

***Proleurocerus*, gen. nov.**

Frons a little prominent, the fronto-vertex more than twice as long as broad with shallow thimble-like punctures. Face inflexed, but not margined. Antennae inserted near the mouth; scape large, broadly foliaceous, oval; flagellum very short, pedicel not longer than broad, the 6 funicle joints transverse, club solid, broader and longer than the funicle. Mandibles narrow, with 3 teeth, the middle one a little longer and more pointed than the others. Axillae meeting in the middle. Wings with the marginal vein punctiform, distant from the margin of the wing, only the end of the short postmarginal vein reaching the anterior margin; stigmal vein narrow, longer than the postmarginal. Abdomen as long as the thorax, the hypopygium protruding beyond the tip of the last tergite.

Type: *P. fulgoridis*, sp. n.

This genus is related by the form of the antennae to *Leurocerus*, Crawford, and *Leuroceroides*, Girault, both of which have a broad scape, transverse funicle joints

and a solid club. *Leurocerus* has the antennae more flattened and foliaceous, like *Cerapterocerus*, and the neururation of the wing similar, but nearer the margin; *Leuroceroides* is quite different by the wing neururation, the distinct marginal vein being longer than the stigmal. This new genus is well characterised by the form of the antennae, the neururation (the marginal vein not reaching the margin of the wing), the form of the mandibles and the prominent hypopygium.

***Proleurocerus fulgoridis*, sp. nov.**

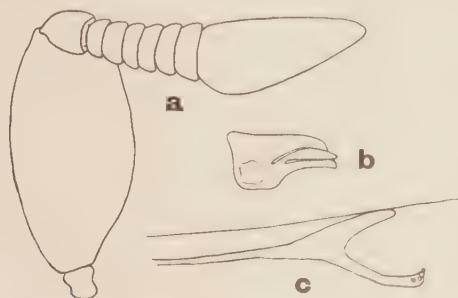


Fig. 8. *Proleurocerus fulgoridis*, sp. n.: a, antenna; b, mandible; c, wing neururation.

♀. Body dark green, especially on head and thorax; abdomen and mesopleurae more brownish black. Antennae brown, the 6th funicle joint white. Wings fuscous, hyaline at base and with two hyaline lines, one longitudinal below the middle of the wing and one short, oblique, just behind the postmarginal and stigmal veins. Legs brown, base and tip of middle tibiae and all tarsi yellow.

Head as broad as the thorax, finely punctate, dull, with larger scattered shallow punctures; eyes large, oval, reaching the hind margin of the head; lateral ocelli almost touching the margin of the eyes and wider apart than from the front ocellus. Face inflexed, much shorter than the fronto-vertex, not margined. Antennae inserted on each side of the clypeus, scape flattened and broadened, about twice as long as broad; pedicel short, as long as broad; the 6 funicle joints small, transverse, of about equal length, but widening from the 1st, which is narrower than the pedicel to the 6th, which is about thrice as broad as long; club large, broader than the funicle at base, obliquely truncate and about as long as the funicle with the pedicel. Mesonotum and scutellum dull, shagreened, with transverse rows of white hairs. Scutellum triangular, reaching the base of the abdomen and covering the middle of the propodeon. Mesopleurae finely striate. Middle tarsi a little shorter than the tibiae; the tibial spur as long as the metatarsus. Abdomen short, triangular, the last sternites more strongly developed than the corresponding tergites, so that the hypopygium is strongly prominent. Ovipositor hidden below the last tergites, not protruding.

Length: 1.25 mm.

INDIA: Bangalore, 5 females, 14.ii.1924 (S. Mahdihassan). Labelled: "Roh. lot. 1783. *Cerapterocerus fulgorid* Mahd. MS."

The type and one cotype are deposited in the British Museum, two cotypes in the U.S. National Museum.

These specimens have probably no other relation with *Tachardia lacca* than that they have been perhaps bred on the same tree. Since writing this description, we have found this same species in the collection of the Imperial Institute of Entomology, bred in SOUTH INDIA, Closepet, Aug. 1931, from the eggs of the Fulgorid, *Eurybrachys tomentosa*. Its relation with *Leurocerus*, Crawford, is thus also biologically confirmed, as *L. ovivorus*, Crawford, is an egg parasite, which has been reared from the eggs of a butterfly in Sumatra.

***Coccophagus tschirchii*, Mahd.**

Coccophagus tschirchii, Mahdihassan, J. Sci. Ass. Vizianagaram, **1**, 1923, p. 72 (sine description).

C. tschirchii, Mahd., Ferrière, Bull. Ent. Res., **19**, 1928, p. 173.

The description and figure which we have published and the notes given by Compere (1931) in his revision of the world's species of *Coccophagus* are sufficient to characterise this species. It belongs to the group of species with the scutellum furnished with only three pairs of bristles and is easily recognised by its striking coloration on the thorax. The axillae and propodeon are generally lighter than the base of the mesonotum and in many specimens they may be quite light brown, almost yellow. The smaller females are generally lighter in coloration, with the head and thorax yellow and only the occiput, the middle of the pronotum, a short anterior part of the mesonotum and the end of the parapsides dark.

The male is darker than the female, with mesonotum, except along the parapsidal furrows, axillae and scutellum, except on the sides, dark brown; abdomen brown; legs and antennae entirely yellow. The antennae are more elongate, the pedicel rounded, the 3 funicle joints similar to those of the female, but the club joints longer.

Length: ♀ 1·1–1·7 mm.; ♂ 1·2 mm.

Since our last note, we have seen specimens from: INDIA: Bengal, 1927 (*C. S. Misra*); Namkum, 1933 (*P. M. Glover*); and MALAYA: Dindings, 1931 (*G. H. Corbett*).

***Marietta javensis*, How.**

Perisopterus javensis, Howard, U.S. Dep. Agric., Tech. Ser. no. 12, pt. 4, 1907, p. 88.

The original description is as follows:—

"Female. Length 0·72 mm., expanse 2·2 mm., greatest width of forewing 0·28 mm. Eyes naked. Pattern of forewings of the reticulated type. Ovipositor well extruded. Mesonotum and mesoscutellum delicately hexagonally reticulate-punctate. General colour orange, sides of thorax and abdomen marked with whitish; abdomen with more or less perfect cross-bands of brownish. Legs pallid; femora with two narrow bands of brown; tibiae with three broad brown bands, broader on middle than on hind tibia, and with a narrow brown tip; first and fifth tarsal joints brownish, others pallid. Antennae with club brown, yellowish at tip; third funicle joint brown, white at tip; first and second funicle joints (ring joints) brown; pedicel brown at base, white at tip.

Male. Smaller. Colour about as with female, but with small white thorax. Entire club brown except somewhat lighter at tip; pedicel whitish at tip.

Type. No. 10346, U.S. National Museum. Described from 7 male and 8 female specimens reared February 1900 from a species of *Tachardia* on an ornamental plant at Singapore, Straits Settlements, by A. Koebele."

We have received from the Indian Lac Research Institute in Namkum a number of specimens which agree exactly with this description; they have been reared from *Tachardia lacca* and *Aspidiotus orientalis*. Their size varies in males and females from 0·5 to 0·9 mm. We add only drawings of the antennae to show the relative length of the joints, and of the wing with the pattern formed by the ciliae. It is probably a parasite of several Coccids in the Indo-Malayan region, but seems still very little known.

The only mention which may refer to this species as a parasite of *T. lacca* is made by Mahdihassan (1923), who says that a *Perisopterus* sp. has been obtained from young Coccids of all sorts of lac. Another species, parasite of *Tachardia lobata*, Green,

in Ceylon is mentioned and described by Girault (1916) under the name of *Marietta leopardina*, Nietner. According to Girault's description, it seems to differ a little in colouration from *M. javensis*, but it is doubtful if it is the same species as *M. leopardina* (Nietner), Motschulsky. Girault says: "Venation as in *Perissopterus* and this genus is the same as *Perissopterus*."

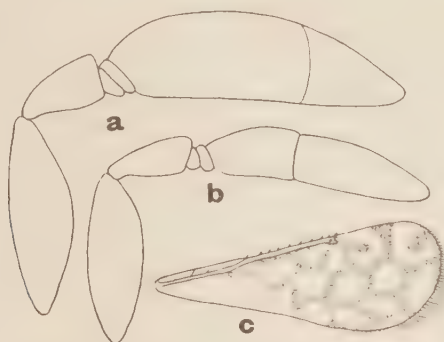


Fig. 9. *Marietta javensis*, How.: a, antenna ♂; b, antenna ♀; c, wing.

This does not agree with the opinion expressed by Mercet (1929) who distinguishes the genera *Perissopterus*, Howard, and *Marietta*, Motsch. Taking into account the short description of *M. leopardina* given by Motschulsky and another species from France, *M. marchali*, Merc., he writes: "*Perissopterus* could remain at least as sub-genus of *Marietta*, as some differences may be observed between them, in relation with the form of the antennae and the spots or design on the anterior wings. In *Marietta* the wings are smoky with rounded hyaline spots, whereas in *Perissopterus* the wings are generally hyaline, with an irregular pattern formed by dark and thick hairs. The antennae of the males are quite distinct in *Marietta* and *Perissopterus*." After Mercet's descriptions the males of *Marietta* have the scape cylindrical and the two funicle joints well developed, although somewhat broader than long; whereas in *Perissopterus* the males have the scape more or less foliaceous below and the two female joints are small and annuliform. Following this *javensis*, How., would be a real *Perissopterus*.

Nevertheless such differences are only probably specific, and we consider, like some American authors, that *Perissopterus* and *Marietta* are the same genus. Dr. Gahan writes to us: "I do not believe it possible to maintain a separation on the basis proposed by Mercet, since there appears to be every gradation in the wing pattern from practically hyaline with only two or three obscure dark patches to the pattern ascribed by Mercet to *Marietta*. As a matter of fact I consider it doubtful that *Marietta leopardina*, Mots., has a wing pattern more like Mercet's species than like *P. javensis*, How. We have in the collection here one specimen reared from *Lecanium coffeae* by E. E. Green in Ceylon and identified by Ashmead as *leopardina*, which is badly broken, but which does not appear to have the wing pattern materially different from *javensis*."

***Elasmus claripennis*, Cam.**

Cyclopleura claripennis, Cameron, Ind. For. Rec., **4**, 1913, pt. 2, p. 7.

Elasmus colemani, Mahdihassan, J. Sci. Ass. Vizianagaram, **1**, 1923, p. 69.

Elasmus claripennis, Cam., Ferrière, Bull. Ent. Res., **19**, 1928, p. 171 & **20**, 1929, p. 418.

Our redescription and study of this species in 1928 and 1929 have shown that it is a well-characterised species in India, parasite of *Eublemma amabilis*, Moore. Since then we have received a large series of females and males from the Lac Research Institute in Namkum, bred also from this same host.

***Tetrastichus purpureus*, Cam.**

Hadrothrix purpurea, Cameron, Ind. For. Rec., **4**, 1913, pt. 2, p. 13.

Tetrastichus immsii, Mahdihassan, J. Sci. Ass. Vizianagaram, **1**, 1923, p. 71.

Tetrastichus purpureus, Cam., Ferrière, Bull. Ent. Res., **19**, 1928, p. 174.

It is also now a well known parasite of *Tachardia lacca* and has been found in different countries. We have seen also specimens bred from *Aspidiotus orientalis*.

Since our last note, we have obtained specimens from : INDIA : Lyallpur, Punjab (Husain), "Associated with lac" ; Namkum (P. M. Glover) ex *Tachardia lacca* and *Aspidiotus orientalis*. CEYLON : Wattagama (J. C. Hulson), ex *Tachardia albizziae*; MALAYA : Rawang (N. C. E. Miller), "from lac incrustation."

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THE BIOLOGY OF *MICROPLECTRON FUSCIPENNIS*, ZETT. (CHALCID.),
A PARASITE OF THE PINE SAWFLY (*DIPRION SERTIFER*, GEOFF.).

By

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1. Introduction.

During the writers' work on the collection of parasites of sawflies of the genus *Diprion*, for introduction into Canada, a Chalcid, *Microplectron fuscipennis*, Zett. (family EULOPHIDAE), was found in considerable abundance parasitising *Diprion sertifer*, Geoff., in Austria, Hungary, and Jugoslavia. As this Chalcid readily attacked the cocoons of *Diprion polytomum*, Htg., the sawfly in Canada against which the introduction of parasites was directed, large numbers were collected in Hungary, and its biology, morphology, and artificial rearing were studied in some detail. An account of this will be given in the following paper.

2. Hosts, Distribution and Climate.

Microplectron fuscipennis appears to parasitise exclusively the genus *Diprion*, being recorded previously on seven occasions only, on *D. pini*, *D. sertifer*, and *D. pallidus*. (Zetterstedt records it under the name *Entedon fuscipennis*, Zett., as a parasite of Lepidopterous pupae from Lapland.) The writers have obtained it in considerable numbers from *D. sertifer*, on which it was mainly primary, but in a small proportion of cases it was apparently hyperparasitic upon a primary Cryptine parasite of *D. sertifer*, *Microcryptus basizonius*, Grav. In one infestation of *D. sertifer* in Hungary, where the parasitism was studied in detail, this Chalcid was

a primary parasite in 71 per cent. of its total parasitism and secondary in 29 per cent. This latter was, however, the result of an overlapping in parasitism, and occurred to the greatest degree where there was the heaviest infestation by *Microcryptus*. In Yugoslavia, where this Chalcid occurred in great abundance and Ichneumonid parasites were conspicuously uncommon, the former was almost entirely primary. *Microplectron*, then, may be regarded as essentially a primary parasite of *D. sertifer*, and only accidentally secondary. Such hyperparasitism is really an aspect of multiple parasitism resulting from the intrinsic superiority of the Chalcid over ICHNEUMONIDAE. It is probable that this superiority is brought about by the very much quicker growth of the Chalcid larvae and the large numbers of eggs laid in a cocoon, so that even if *Microplectron* oviposits in a cocoon containing a well-advanced Ichneumonid larva it would be capable of overtaking and eventually destroying the latter.



Fig. 1. *Microplectron fuscipennis*, Zett., female; a, antenna of male ($\times 28$).

There appears to be a hyperparasite of *Microplectron* in an apterous Chalcid, *Eupelmella vesicularis*, Rätz. About a dozen specimens of this insect have been obtained from *D. sertifer* cocoons from Hungary and Yugoslavia, and in every case the cocoon from which *Eupelmella* emerged contained the remains of *Microplectron fuscipennis* adults, pupae, and larvae. The adults were dead and uninjured, but in

each cocoon most of the pupae and some larvae were unmistakably damaged and sucked dry, the rest dead and shrivelled. Although it would require breeding experiments to prove conclusively that *Eupelmella vesicularis* is hyperparasitic upon *Microplectron*, yet circumstantial evidence points strongly to this conclusion. Firstly, there is the fact that *Eupelmella* was invariably associated with *Microplectron*; secondly, the fact that *Microplectron* had reached adult and pupal stages before being destroyed, indicating that *Eupelmella* laid in the cocoon after *Microplectron*, thereby exercising deliberate choice in such cases.

The geographical range of *Microplectron* is wide; records come from Scandinavia (Zetterstedt, 1840; Thomson, 1876; Ruschka, 1924), Poland (Sitowski, 1925; Mokrzecki, 1927), Holland (De Fluiter, 1932), Germany (Hartig, 1837; Ratzeburg, 1844; Scheidter, 1934), and Austria (Schonwiese, 1934). During the present work it has been bred from *D. sertifer* in a number of localities in Austria, Hungary, and Jugoslavia, and specimens have been received from the same host from Sweden.

It is evidently capable of tolerating considerable diversity of climate. Professor Trägårdh writes that it is a very common parasite of *D. sertifer* in Sweden; it is recorded by Sitowski as "common" on *D. pini* and *D. sertifer* in the vicinity of Posnen, and Mokrzecki mentions it as "especially numerous on both *D. pini* and *D. pallidus*" at Skierniewice, just south of Warsaw. All these are regions of rigorous climate, with long and hard winters and short, hot summers, but it seems to reach its maximum abundance in a warmer, more southerly climate. Thus, in the present work it has been found in Austria giving only 2-3 per cent. parasitism, in Hungary showing 10-15 per cent., and along the Adriatic coast-line of Jugoslavia reaching as much as 80 per cent., never less than 33 per cent. This abundance in Jugoslavia cannot be regarded as due to the direct influence of climate alone upon the Chalcid, but is the result of a whole complex of factors, at the root of which, indeed, is climate. The first, and direct, effect of the very long and hot summer in this locality is double; a lengthening of the breeding season and a shortening of the life-cycle. Thus it was found, in the localities of maximum abundance, that all available cocoons of *D. sertifer* had been parasitised, and the majority of parasites had emerged by the beginning of August; and since there are no other species of *Diprion* present and *D. sertifer* has but a single generation in the year and, so far as could be ascertained, *Microplectron* had no other hosts, its numbers must suffer severe reduction in late summer and autumn. This would leave a very small proportion of living parasites by the time new host cocoons are available at the end of the following May, yet between then and August it attains abundance. The rate of increase must, indeed, be amazingly rapid. In considering this sequence of events, it is rather surprising that *Microplectron* does not reduce both itself and its host to the point of extinction. The answer is that the host, *D. sertifer*, is maintained by a small proportion of cocoons that are in positions inaccessible to the parasite, usually because they are deeply buried in the soil; in the case of the Chalcid a certain number of larvae go into diapause, even in this climate, in August, and these will not emerge until the following spring. These points are more fully treated in the next section on biology. A second and most important factor in bringing about the abundance in Jugoslavia is the presence of a very large supply of easily available host material. Along certain parts of the coast the sawfly is present every year in more or less large numbers (owing to the favourable climate) and spins its cocoons almost exclusively upon the tree-trunks, where they are readily accessible to the Chalcid. Cocoons spun on the ground are seldom deeply hidden, because of the scanty layer of pine-needles and hard rocky soil. The importance of a regularly abundant and easily available host in bringing about heavy parasitism by this Chalcid is emphasised by comparing these conditions with those obtaining in an infestation studied at Izsák in Hungary. The summer here is almost as long and quite as warm as that of the Jugoslavian coast, though considerably drier, and the winter is much colder. Infestations of *D. sertifer* here are sporadic, occurring for two or three years at long intervals and

the cocoons are spun only on the ground and mostly buried one or two inches beneath a thick layer of pine-needles. The cocoons lie for approximately the same length of time as in Yugoslavia, from May to September, yet the maximum parasitism reached was only 10 per cent., in the beginning of August. As mentioned above, this Chalcid was found in many localities in Hungary and Austria, but parasitism was never above 16 per cent., usually considerably less. It seems difficult to believe that the small difference in climate could bring about such a disparity in numbers, and the regular supply of host material and the exposed position prevailing in Yugoslavia must be deeply significant. The precise response of this insect to climate can best be determined by laboratory experiment. This is being done by Mr. G. C. Ulyett at Farnham House Laboratory, and the results will be published in a later paper.

3. General Bionomics of *Microplectron fuscipennis*.

The main study of this parasite in the field was made at Izsák, in Hungary, at the scene of an infestation of *D. sertifer* already mentioned. The date of the earliest appearance of *Microplectron* is not known, as this locality was not visited until 18th June, when cocoons were found containing full-grown larvae and pupae of this parasite, the first adults emerging a few days later. The life-cycle, under natural conditions during July, with a mean monthly temperature of just over 23°C. and relative humidity of 80 per cent., was found to occupy 15 to 18 days. Laboratory studies have since shown that the life-cycle at 21°C. and 70 per cent. relative humidity, averages 21–23 days. As the June temperature at Izsák was only 19°C., it will be seen that the Chalcid must have been present, and have oviposited, at the end of May at the time when the sawfly cocoons were first spun. As the sawflies do not emerge until the middle of September, and the mean temperature remains above 21°C. throughout August and September, there is time for four complete generations to develop in this locality. This did, indeed, take place in one batch of *Microplectron*, reared in a large glass jar in an open unheated room, the temperature and humidity conditions of which approximated to those in the field. The first generation of adults was placed with an abundant supply of cocoons on 29th June, the emergence of the second generation of adults took place between 15th and 21st July, the third generation was observed on 9th August, and the fourth generation during the first week in September. In the field, however, there was so much spreading out and overlapping of generations, owing to continued emergence of adults, that it was impossible to determine the number of generations undergone. Certainly some families do not go through more than two or three generations, as a large proportion of full-grown larvae were already going into diapause in August, and practically 80 per cent. were doing so in the beginning of September. Such individuals would pass the winter in the prepupal stage, and pupate and emerge in the following spring. This early diapause is a most important factor for maintaining a stock of the parasite despite the absence of alternative hosts, as has been pointed out in the previous section. Mention has already been made of the position of this parasite in Yugoslavia, where the maximum parasitism is attained between May and the end of July, from what must be a small overwintering population. The high temperature of this district would ensure at least as rapid a development as in Hungary. June, July and August have a monthly mean temperature of 21°, 23°, and 22°C. respectively, and one might expect 3, 4, or 5 generations in the year, though this has not yet been investigated. In one locality in Austria, in Unterwaltersdorf near Vienna, where *Microplectron* was present in only 2 per cent. of cocoons of *D. sertifer* in July, there were certainly only two generations in the summer, the second going into hibernation as prepupae early in August.

The length of life of the adult *Microplectron* in the laboratory averaged from ten days to a fortnight. In one large batch of males and females kept at 18°C. and 50 per cent. R.H., all the individuals lived at least one week; from the eighth day



Fig. 1. Rearing jar



Fig. 2. Enlargement of cocoon strip, showing adults ovipositing

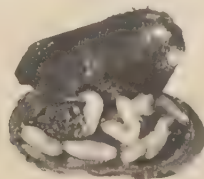


Fig. 3. Opened cocoon showing mature larvae.

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MICROPLECTRON FUSCIPENNIS

onwards a number died daily, so that at the end of the second week the original number was reduced to half; at the end of the third week only one-fifth of the original population was alive, and at the end of the fourth week only one-sixteenth. The last female died on the thirty-second day after emergence.

There is always a very marked disproportion in the numbers of each sex emerging both in the field and in the laboratory, females being greatly in excess of males. The greatest difference was found in Hungary, where one male to six females was the average. In Yugoslavia the proportion was 1:4, and the same proportion was found in about a thousand individuals bred in the laboratory.

Mating takes place immediately after emergence. The very active male springs upon the back of the female and starts to caress her antennae, which are held erect, with his own, at the same time swinging his body backwards and forwards, raising and lowering his abdomen, and keeping up a rhythmic vibration of the wings the while. Occasionally he rests his body but keeps up the motion with his antennae. When the female is sufficiently excited she raises her abdomen, the male moves back and curves his abdomen round and under hers, in order to effect penetration and copulation. The whole process, including the preliminary courtship, occupies about a minute. Often a female will allow a male to mount her and caress her antennae, but will later resist any attempt at copulation.

Oviposition is effected through the sawfly cocoon on the prepupa. A female spends a long time on a cocoon, laying up to 20 or more eggs therein. In experiments, individual females laid, on the average, 45 eggs each, and the maximum number was 124 eggs for one individual. In conducting these experiments it was found that a certain percentage of females never laid any eggs (the cause of this is unknown) and these were eliminated from the computation. Unmated females oviposit freely and the eggs develop in the usual way, but result in an entirely male progeny.

The number of individual *Microplectron* emerging from a single cocoon was found to vary tremendously, from 5 to 119 in cocoons parasitised naturally in the field, and 120 is the highest number bred from a cocoon in the laboratory. The average number of individuals from a cocoon was found to vary according to locality; in Hungary it was 30.7, in Yugoslavia 72.5. Such large numbers undoubtedly result from the oviposition of several females in one cocoon, which would occur most commonly where the parasitism is highest. In such places superparasitism is also common. In one cocoon from Yugoslavia 164 eggs and 68 developing larvae of *Microplectron* were found.

As might be expected, a Chalcid with such powers of reproduction and such rapid development is capable of attaining a high degree of parasitism. The highest figure found was at Crkvenica on the Yugoslavian coast of the Adriatic, where 78 per cent. of *D. sertifer* cocoons held Chalcids; and at Senj, 20 miles south and still on the coast, 77 per cent. of cocoons. These figures cannot represent the full parasitism attained, as 15 per cent. and 12 per cent. of the cocoons in these two localities were destroyed by predators, which certainly show no discrimination in what they eat. At higher altitudes along this coast, from 300 metres upwards, the parasitism diminished in a marked degree, until at 600 metres only 33 per cent. was observed. This may be due, to a certain extent, to the slightly colder climate, but it is probably due mainly to the fact that at these altitudes the sawfly is less numerous and more sporadic in its outbreaks, large numbers being found, not every year, as on the coast, but only during epidemics occurring at longer intervals. One point has been mentioned before but may be stressed here again, as contributing to the high degree of parasitism found in Yugoslavia. This is the position in which the host cocoons are spun, mainly upon the tree-trunks, and when on the ground never deeply buried, owing to the lack of a thick needle or grass layer in the forest. This rendered them readily available to the Chalcid, which could reach the cocoons everywhere, though practically all the cocoons on the ground were subsequently destroyed by mice,

causing proportionately equal losses to hosts and parasites. In Hungary such parasitism was never found, 16 per cent. being the highest, at Cspel, close to Budapest, and an average of 10 per cent. at Izsák. One of the main reasons for this low rate was the inaccessible position of the cocoons generally in Hungary. Most of the pine forests here are on flat, sandy soil, with a thick covering of needles and sometimes grass. When such a covering exists *D. sertifer* spins its cocoons for preference on the forest floor, at any depth from superficially, on top of the needles, to two to three inches below the needle layer and just buried in the sand. Now this Chalcid apparently had not great powers of penetrating to these deeper layers, and the parasitism was always much greater in the case of surface cocoons than in those from the deeper layers, the difference being as much as 9 per cent. in extreme cases. This failure of the *Microplectron* to penetrate far into the needle layer meant that, in effect, only a small proportion of the cocoons, those at the top, was available for its oviposition. Another interesting observation made in this district showed that there was considerable local variation in this parasite's distribution within the infested area. In general, the parasitism was greatest where there was the greatest abundance of host cocoons, in the outlying and thinly infested areas it was comparatively scarce. Samples of 100 cocoons showed a variation in parasitism of 10 per cent. and 1 per cent. for different parts of the wood at the same time. It has already been mentioned that in Austria the parasitism by this species was low, approximately 2 per cent. at Unterwaltersdorf in the north, and about 3 per cent. in South Carinthia. The parasitism attained in Sweden has not been determined, and none of the writers quoted in the preceding section give any figures at all.

4. The Egg.

The eggs (fig. 4, *d*) are laid through the cocoon on the skin of the prepupa; they adhere slightly to one another and are usually in groups of up to 20 or more. They are white in colour and sub-reniform in shape, tapering more acutely towards one end. The surface is shining and appears to be smooth under low magnification, but under high powers of the microscope it is seen to be covered with minute conical projections.

Length of egg, 0.34 mm.; maximum breadth, 0.11 mm. At a temperature of 22°C. and 70 per cent. R.H. hatching takes place on the second or third day after oviposition.

5. Larval Instars.

There are five larval instars. The main points of difference between them are: size, the shape of the mandibles, the tracheal system and number of spiracles, and the number and size of the papillae. In the primary larva the mandibles are strongly curved, in the succeeding instars they are more or less straight. There are only four pairs of tracheae in the first-stage larva, in the mature, or fifth-stage, there are nine. The breadth of the head-capsule of each instar is as follows: 1st instar, 0.096 mm.; 2nd, 0.128 mm.; 3rd, 0.168 mm.; 4th, 0.224 mm.; 5th, 0.304 mm. These figures, providing a close and persistent ratio between the successive instars (1.33), gave a useful indication of the number of stadia, which was confirmed by mounts of each larval instar showing the newly-moulted head-capsule and parts of the skin of the preceding one. Each of the first four stadia occupies a period of one day, sometimes a few hours longer, and the 5th or final instar continues feeding for a further period of about four days after the 4th ecdysis. It then finishes feeding and becomes a resting larva, remaining in this stage for two to three days until it assumes a definite prepupal form.

6. Primary Larva.

The primary larva consists of a head and 13 clearly defined body segments; the skin is transparent and glistening. It is somewhat fusiform in shape, being

broader anteriorly and tapering more towards the posterior extremity. The head is narrower than the first few segments. Length of primary larva, 0.35-0.38 mm.; maximum breadth, 0.11 mm.

The head is somewhat hemispherical in shape, and its chief features are a pair of antennae and a fairly well-developed internal skeletal system. The main function of this chitinised head skeleton (fig. 2) appears to be the support of the mandibles and the various mouth-structures associated with feeding. It also gives a certain amount of rigidity to the head. The mandibles, which are well developed and strongly arched, articulate on the superior and inferior mandibular struts. In the upper articulation the condyle is on the strut, while in the lower this order is reversed, the condyle being on the mandible. These mandibular struts or supports are joined together by the pleurostoma, while the inferior mandibular struts in this species are fused together to form a continuous rod underneath the mouth. The epistoma, an arch above the clypeus, arises from the superior or dorsal ends of the pleurostoma, while the hypostoma, consisting of a pair of long curved rods, is given off from the inferior or ventral ends. The hypostoma connects with the internal arched tentorium.

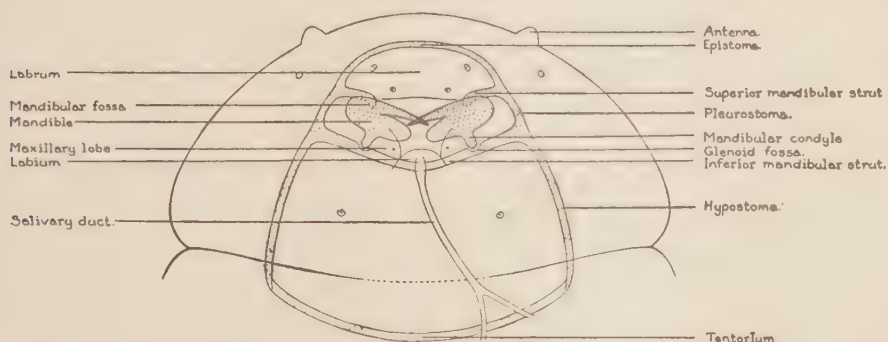


Fig. 2. Head of primary larva, showing head skeleton and various mouth appendages ($\times 350$).

Of the non-chitinised mouth-parts, the labrum with two pairs of papillae, the maxillary lobes, each with a small papilla, and the labium are fairly well defined. The salivary duct, produced by the union of two internal tubes, is also clearly discernible. It opens into the mouth in the labial region. A pair of papillae are present in the labial region within the hypostoma, and another pair outside the supporting skeleton near the superior mandibular struts.

The tracheal system of the primary larva consists of two longitudinal trunks extending from segment 2 to 11. In segments 2, 4, 5, and 6 a lateral branch is given off from each trunk in the anterior portion of the segment to connect with an external spiracle, four pairs in all; while in segments 3 and 7-11 short, incipient branches are clearly defined. Anteriorly in segment 2 the two longitudinal trunks are joined by a transverse commissure, which gives off a pair of bifurcating branches to the first segment and the head-capsule. Posteriorly in segment 11 the longitudinal trunks are also transversely connected, and two branches project backwards into segments 12 and 13. From the point where the lateral and incipient lateral branches are given off a large number of very fine tracheae arise and ramify through the body of the larva.

7. Mature Larva.

The fifth-stage larva (fig. 4, *a*) consists of a head and 13 body segments, the segmentation being well, but not so clearly defined as in the primary larva. The main part of the body is orange-yellow in colour, but the head, first segment, part

of the second and last three or four segments are more or less transparent. It is cylindrical in shape, with a comparatively narrow head anteriorly, tapering posteriorly, and usually curved round ventrally, an aid to sticking on to its host. The last segment has a transverse indentation posteriorly.

The cuticle of the body is shiny and almost glabrous—only with a very high power of the microscope can a few small scattered papillae be seen. The head is hemispherical in shape and glassy-white in colour. It is divided into three lobes, a pair of dorso-anterior or epicranial, each bearing a conspicuous antenna, and an antero-ventral lobe below the mouth.

The average length of the fully extended larva is 3.36 mm. and its maximum breadth 0.86 mm.

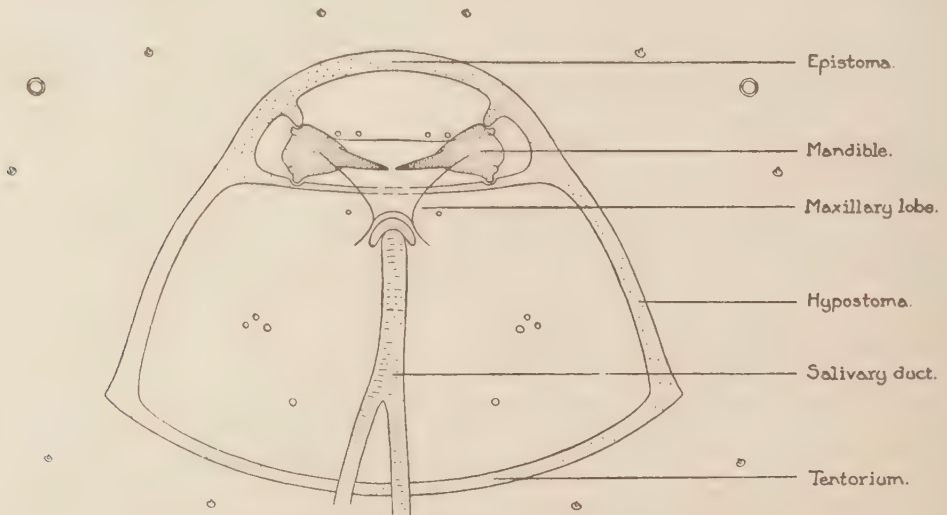


Fig. 3. Head of mature larva, showing head skeleton and various mouth appendages (\times about 187).

The skeleton of the head (fig. 3) resembles that of the primary larva—epistoma, pleurostoma, superior and inferior mandibular struts, hypostoma, and tentorium all being present. In this instar the rod formed by the fused inferior mandibular struts is not so clearly defined as in the primary larva, and the mandibles are also different. Instead of being strongly arched, they are now almost straight and supported on strong triangular bases. The annulated salivary duct formed from the fusion of two internal ducts is a prominent structure. Near the point where it enters the mouth in the labial region it is partly surrounded by an inverted U-shaped chitinous rod. A number of papillae are present—one very large and marked pair outside the supporting skeleton in a line (one on each side) with the superior mandibular articulation. There are also three pairs of smaller papillae in this region. A further two pairs are situated on the skin underneath the region of the tentorial-hypostomal connection. On the area within the supporting skeleton the following papillae are present: two pairs on the labrum, a pair on the maxillary lobes, two sets of three on the sub-labial region, and a final pair below this latter group. The antennae, when viewed from above, are seen to have two small papillae on their upper surface.

There are nine pairs of spiracles present (fig. 4, *c*) in segments 2–10, and the general tracheal system of longitudinal tubes and branches is similar to that described for the primary larva.

8. Prepupa.

The cessation of feeding by the mature larva marks the beginning of the prepupal stage. For two or three days it remains unchanged in appearance and then becomes clearly demarked into three new regions (fig. 4, *b*), destined to be the head, thorax, and abdomen of the pupa. The head region is composed of the old larval head and first segment. Behind this a slight constriction appears separating it from the two thoracic segments now much enlarged, which are themselves separated from the abdomen by a similar constriction. Defaecation usually coincides with this change, and as a result the prepupa assumes a white colour. Twenty-four to 30 hours after this change the prepupa moults and enters the pupal stage.

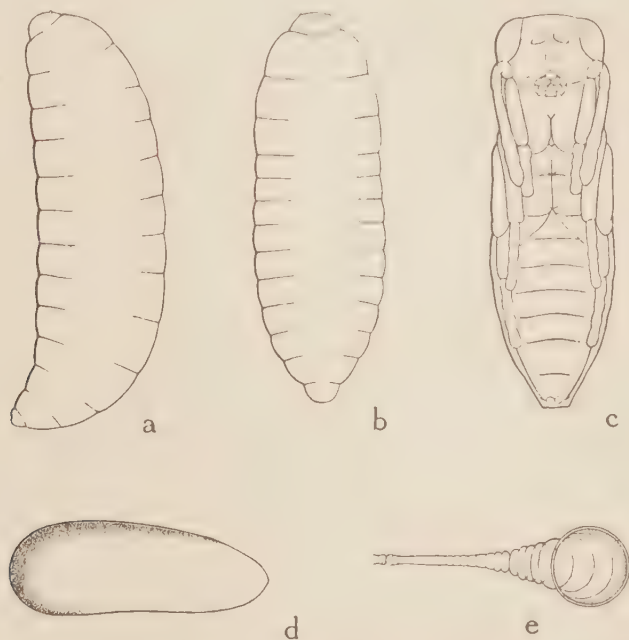


Fig. 4. *Microplectron fuscipennis*; *a*, mature larva; *b*, prepupa; *c*, pupa (all $\times 10$); *d*, egg ($\times 60$); *e*, spiracle of mature larva ($\times 300$).

9. The Pupa.

In the newly formed pupa (fig. 4, *c*), which is white in colour, both wing and leg rudiments can be clearly seen glued to the body. The eyes, mouth-appendages, thoracic and abdominal segmentation are also fairly well defined. After some hours the white colour changes to deep orange, and black pigment is deposited on the abdomen both dorsally and ventrally, and to a less extent on the thorax dorsally. In a day or two the whole of the pupa darkens, although the former ground-colour of deep orange is still discernible, particularly in the intersegmental areas. More pigment is gradually deposited until the pupa becomes quite black.

The average length of the pupal stage is 7–8 days.

10. Rearing in the Laboratory.

Since *Microplectron* has never been found naturally parasitising cocoons of *Diprion polytomum*, the whole success of the introduction depended upon its willingness to do so. This was tested in the laboratory, and in order to make the

tests more significant, cocoons of *D. polytomum* from Canada were used throughout the experiments. Owing to its readiness to mate and oviposit, the fairly high number of eggs per female, and the short life-cycle, it was easy to maintain a large stock of the parasite in captivity.

Rearing was carried out on a small scale in glass cylinders, 4½ in. by 3½ in., having the top covered with muslin secured by a rubber band, and the bottom resting on filter paper inside the cover of a petri dish. Water was supplied from damp cotton wool covered with muslin in a glass receptacle, and food by a lump of sugar and a raisin. Up to 100 females with males were placed in each cage. Cocoons of *Diprion polytomum*, gummed on a strip of paper, were then introduced into the cylinders and the latter placed on shelves in the room window, where the maximum amount of light could be obtained. The room temperature was 18°C. and the relative humidity 40–45 per cent. For the first day or two after emergence the females were rather slow in ovipositing, but from the third day onwards egg-laying was rapid. Fresh cocoons were placed in the cages two or three times a week and the old ones transferred to the constant temperature and humidity room (22°C. and 70 per cent. R.H.), where the complete life-cycle occupied a period of about 3 weeks.

In mass breeding large bell jars, 12 in. by 8 in., were used. These were prepared in the same way as the smaller cages, with the exception that the cocoons were gummed on cardboard strips on four sides of a piece of wood (Plate xvi). Such jars held large numbers of adults and enabled us to carry on a large rearing programme with a minimum amount of attention.

11. Value as a Parasite of *Diprion polytomum*, Htg.

In view of the fact that cocoons of *Diprion sertifer* containing nearly eight millions of this parasite were collected in Hungary and despatched to Canada during 1934, it is not out of place to discuss briefly the prospects of *Microplectron* as a parasite and controlling agent of *D. polytomum* in Canada. Criticism of the whole project might be well made here, when it is realised that this Chalcid has never been found on *D. polytomum* in Europe, despite their having the same geographical range. A knowledge of the status of the Spruce Sawfly in Europe, however, affords a ready explanation and allays such doubts as might be felt. In Europe *D. polytomum*, though widely distributed, is a comparatively rare insect. It has solitary larvae, and its cocoons are scattered and well hidden. Its numbers vary tremendously from year to year and from place to place; an infestation has only once been recorded, and then it was of negligible extent and disappeared in two years. Thus, the most important conditions reproduced by *D. sertifer*, abundance and regular appearance, are entirely lacking in *D. polytomum* in Europe, and the absence of this parasite is at once understood. In Canada, as will be pointed out, the status of the latter sawfly is entirely different.

The first and essential point, that this parasite will oviposit readily in cocoons of the Canadian *D. polytomum*, has been amply proved in the laboratory, both at Farnham House and in Canada. All the experiments at Farnham House have been performed with cocoons sent over from Canada, and the success of this rearing fully demonstrates the attraction and suitability of this host for *Microplectron*. Any final doubts must be swept away by the news, just received, of the recovery of this parasite from *D. polytomum* cocoons in at least three localities in Canada, where liberations were made only last summer.

Equally important is the suitability of the Canadian climate for the establishment and increase of this Chalcid. If one may judge from its geographical range in Europe, there should be no question as to its establishing itself in Canada, at least in the lower regions of New Brunswick and Quebec, where the temperature range is not very different from that of South Sweden or Central Poland. Its establishment

in the high regions of the Gaspé Peninsula, the site of the original infestation of *D. polytomum*, will depend largely on its ability to withstand a low temperature for five or six months of the year, the winter here being both longer and considerably colder than in the parts of Europe mentioned. Actually this, in itself, should not be detrimental to the parasite, as the cocoons in which it overwinters will be buried deeply in snow, but owing to the shorter summer and lower temperatures (considerably below those of Sweden or Poland) the breeding period in the Gaspé will be very much curtailed and the rate of development rather slower. The places where it is likely to be most successful will be the lower country of New Brunswick, round the coast-line, and along the shores of the St. Lawrence. As it is common right down to the shore along the Adriatic coast, it has the advantage of being able to flourish in a maritime climate, with a considerable amount of salt in the air.

The regular abundance of the host experienced in the infested area in Canada is a most decided advantage. The fact that a large proportion of the sawfly prepupae, normally overwintering in the cocoon, remain in diapause for one or two years, ensures an ample supply of cocoons throughout the summer, on which the parasite might pass through successive generations as long as the weather is favourable. This is probably one of the most influential factors in enabling it to attain a high degree of parasitism.

The position of the host cocoons, as we have seen, is also of great importance. In Canada the majority of the cocoons are spun upon the forest floor. If this has a thick layer of needles and moss, parasites will be adversely affected, but if the needle layer be thin, or cocoons occur upon trunks or branches (for example in warmer localities where the host is bivoltine) it will have full scope for its activities.

The fecundity of this species is its greatest asset. Its rate of increase is tremendous, a female laying from 50 to 100 eggs in six or seven days. This is discounted somewhat by the invariable habit of multiple oviposition, from 10 to 50 or more eggs are laid in the same cocoon, so that the parasitism is not spread out to the best advantage. Nevertheless, the rate of increase is not diminished, as all the eggs usually hatch and develop successfully, 120 imagines having been reared from a single cocoon. Besides being a rapid and reproductive breeder, it will breed under almost any conditions, copulation and oviposition following immediately upon emergence and the full complement of eggs being laid generally within a week, so that the presence of food and moisture, though undoubtedly prolonging life and increasing fecundity, are by no means essential. For this reason mass production of the parasite in the laboratory is comparatively simple. This again is a point in its favour, as by mass breeding and by obtaining large numbers of heavily parasitised cocoons from Yugoslavia it would be possible to make really adequate liberations at a great many points in the infested area, a most essential proceeding in dealing with an outbreak of such colossal extent as that of *D. polytomum* in Canada.

It will thus be seen that we have in *Microplectron fuscipennis* a hardy parasite possessed of that most essential quality, a rate of increase considerably more rapid than that of its host; and, furthermore, that in Canada are reproduced, except for climate, those conditions prevailing in Yugoslavia—an absence of alternate hosts and a regular and abundant supply of *Diprion*. Moreover, this supply of hosts undergoes, at present, none of that seasonal reduction brought about by the parasite itself in Europe.

12. Summary.

Cocoons of *Diprion sertifer*, Geoffr., containing nearly eight millions *Microplectron fuscipennis*, Zett., were collected in Europe in 1934 and despatched to Canada for the control of the Spruce Sawfly, *Diprion polytomum*, Htg.

This parasite is widely distributed throughout Europe as a primary parasite of several species of pine sawflies of the genus *Diprion*.

A full account of the biology and a detailed description of the various stages is given.

In the laboratory it was reared in large numbers on the cocoons of *D. polytomum* from Canada.

Its chances of success in Canada depend on its acclimatisation and the accessibility and quantity of host material. Its tremendous fecundity and rapid rate of increase are greatly in its favour.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st April and 30th June, 1935 :—

Mr. D. J. ATKINSON :—1,550 Parasitic Hymenoptera ; from Burma.

Mr. E. BALLARD, Government Entomologist :—18 Diptera and 20 Mites ; from Palestine.

Dr. H. F. BARNES, Rothamsted Experimental Station :—4 Parasitic Hymenoptera ; from Algeria.

Mr. A. F. BELLAIRS :—80 Dipterous larvae, 24 Coleoptera and 5 larvae ; from Brazil.

Mr. P. BORG :—1 Siricid ; from Malta.

Mr. H. E. BOX :—100 Parasitic Hymenoptera ; from St. Lucia.

Mr. H. J. BRÉDO :—43 Coleoptera, 2 Lepidoptera and 2 early stages, and 30 Rhynchota ; from the Belgian Congo.

Prof. P. A. BUXTON, London School of Tropical Medicine :—4 Cleridae ; from England.

Mr. J. CARROLL :—6 Coleopterous larvae ; from the Irish Free State.

Mr. H. F. CARTER :—2 Ephemerid larvae ; from Ceylon.

Mr. K. S. F. CHANG :—121 Orthoptera ; from China.

CHIEF ENTOMOLOGIST, PRETORIA :—10 Diptera, 15 Coleoptera, 200 Parasitic Hymenoptera, and 1 species of Aphidae ; from South Africa.

COCONUT EXPERIMENT STATION, CELEBES :—150 Parasitic Hymenoptera and early stages ; from the Dutch East Indies.

Mr. G. H. CORBETT, Government Entomologist :—38 Diptera, 33 Coleoptera, 18 Parasitic Hymenoptera, 6 Formicidae, 40 Lepidoptera, 90 Isoptera, 26 Rhynchota, and 5 Orthoptera ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—7 Streblidae, 5 Hippoboscidae, 985 Coleoptera, and 28 Odonata ; from East Africa.

Mr. D. S. COWAN :—2 Curculionidae ; from the British Cameroons.

Mr. A. CUTHBERTSON, Assistant Entomologist :—7 Tabanidae and 54 other Diptera ; from Southern Rhodesia.

Dr. A. DA COSTA LIMA :—1 Curculionid ; from Brazil.

Mr. R. C. M. DARLING :—2,000 Orthoptera ; from the Sudan.

Dr. W. M. DAVIES :—2 Siphonaptera and 1 species of Aleurodidae ; from Wales.

Mr. J. DE LÉPINEY :—38 Parasitic Hymenoptera and 50 cocoons ; from Morocco.

Mr. B. DE MEILLON :—111 Tabanidae, 2 Hippoboscidae, 11 *Glossina*, 118 other Diptera, 6 Curculionidae, and 5 Hymenoptera ; from South Africa.

DEUTSCHES ENTOMOLOGISCHES INSTITUT :—82 Parasitic Hymenoptera ; from various localities.

Mr. HARI DEV :—25 Parasitic Hymenoptera ; from the Punjab, India.

Mrs. H. R. P. DICKSON :—5 Coleoptera and 50 Orthoptera ; from Arabia.

Miss Z. DICKSON :—15 Orthoptera ; from Arabia.

DIRECTOR OF AGRICULTURE :—67 Orthoptera ; from British North Borneo.

DIRECTOR OF PUBLIC WORKS, LAGOS :—550 Isoptera ; from Nigeria.

Mr. V. H. W. DOWSON :—158 Rhynchota and nymphs ; from Iraq.

Prof. J. C. FAURE :—3 Orthoptera ; from South Africa.

Mr. J. L. FROGGATT, Government Entomologist :—88 Coleoptera, 16 Hymenoptera, 21 Lepidoptera, 50 Rhynchota, and 13 Orthoptera ; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—36 Diptera and 17 pupa cases, 143 Curculionidae, and 9 Lepidoptera ; from the United Provinces, India.

Mr. S. GARTHSIDE :—2 Parasitic Hymenoptera ; from France : and 16 Coleoptera, 5 Parasitic Hymenoptera, 6 Lepidoptera, and 5 Rhynchota ; from England.

Mr. C. C. GHOSH :—83 Coleoptera, 336 Parasitic Hymenoptera, and 135 Lepidoptera ; from Burma.

Mr. F. D. GOLDING, Government Entomologist :—37 Lepidoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—19 Lepidoptera ; from South India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—10 Coleoptera and 250 Mites ; from the Punjab, India.

Mr. A. GRASSET :—35 Parasitic Hymenoptera ; from Algeria.

HAMBURG MUSEUM :—120 Parasitic Hymenoptera and 700 cocoons ; from Germany.

Mr. K. J. HAYWARD :—5 Lepidoptera ; from the Argentine.

Mr. H. J. HOCKINGS :—35 Coleoptera, 300 Parasitic Hymenoptera, and 12 Lepidoptera ; from Queensland.

Mr. W. E. H. HODSON :—1 Agromyzid and 1 Braconid ; from England.

Mr. G. V. HUDSON :—85 Coleoptera ; from New Zealand.

IMPERIAL CHEMICAL INDUSTRIES, LTD. :—25 Dipterous larvae ; from England : and 2 Apidae ; from the Irish Free State.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—120 Coleoptera, 56 Lepidoptera, 1 species of Coccidae, 5 other Rhynchota, and 1,000 Mites ; from the Dutch East Indies.

Mr. C. B. R. KING :—2 Diptera and 3 puparia, 12 Coleoptera, 33 Parasitic Hymenoptera and 9 cocoons, and 10 Psocidae ; from Ceylon.

Mr. L. A. L. KING :—6 Coleoptera ; from West Africa.

Mr. T. W. KIRKPATRICK :—14 Strepsiptera and 100 early stages, and 30 Pentatomidae ; from Kenya Colony.

Mr. H. M. KNATCHBULL-HUGESSEN :—2 Gryllidae ; from Persia.

Dr. LL. LLOYD :—4 Coleoptera ; from England.

Mr. A. MANJIKUL :—117 Diptera and 2 pupa cases, 260 Parasitic Hymenoptera, and 71 Lepidoptera ; from Siam.

Mr. J. C. VAN DER MEER MOHR :—26 Coleoptera ; from Sumatra.

Prof. F. J. MEGGITT :—9,000 Isoptera, 2 Thysanura, and 30 Crustacea ; from Burma.

Mr. J. MUGGERIDGE, Government Entomologist :—12 Coleoptera, 8 slides of Thysanoptera, and 1 species of Eelworm ; from New Zealand.

MUSÉE NATIONAL D'HISTOIRE NATURELLE, PARIS :—50 Parasitic Hymenoptera ; from the Cape Verde Islands.

Mr. F. B. NOTLEY, Assistant Entomologist :—30 Parasitic Hymenoptera, 1 species of Coccidae, and 11 other Rhynchota ; from Kenya Colony.

OXFORD UNIVERSITY EXPEDITION :—4,200 Coleoptera ; from Sarawak.

Messrs. H. T. PAGDEN and R. A. LEVER, Government Entomologists :—35 Siphonaptera, 25 Culicidae, 11 Tabanidae, 343 other Diptera, and 3 pupa cases, 300 Coleoptera, 23 Parasitic Hymenoptera, 36 other Hymenoptera, 65 Lepidoptera, 1 species of Coccidae, 233 other Rhynchota, 25 Orthoptera, 4 Dermaptera, and 4 Birds ; from the Solomon Islands.

Mr. H. J. PHILLIPS :—1 Tachinid ; from England.

Rev. O. PIEL :—105 Orthoptera ; from China.

Dr. S. V. PILL :—2 Psychid cases and 57 Orthoptera ; from South Persia.

Dr. H. PRIESNER :—10 Cecidomyiidae and 20 larvae ; from Egypt.

Mr. P. REGNIER :—385 Coleoptera ; from Morocco.

Mr. A. H. RITCHIE, Government Entomologist :—12 Dipterous larvae, 42 Coleoptera, and 5 Parasitic Hymenoptera ; from Tanganyika Territory.

SELANGOR MUSEUM :—278 Coleoptera ; from Malaya.

Mr. H. W. SIMMONDS, Government Entomologist :—14 Parasitic Hymenoptera, 7 Thysanoptera, and 3 species of Coccidae ; from Fiji.

Mr. H. D. SMITH :—32 Parasitic Hymenoptera ; from Egypt.

Mr. F. A. SQUIRE, Government Entomologist :—10 Diptera, 39 Coleoptera, 159 Parasitic Hymenoptera, and 9 slide preparations, 300 Formicidae, 12 Lepidoptera, 10 Isoptera, 11 Rhynchota, 2 Blattidae, 8 Embiidae, and 7 Crustacea ; from British Guiana.

Mr. T. V. SUBRAMANIAM, Entomologist :—6 Diptera, 35 Coleoptera, 100 Parasitic Hymenoptera, and 11 Lepidoptera ; from Mysore, India.

Mr. E. SURÉN :—50 Rhynchota ; from Iraq.

Dr. D. C. SWAN :—9 Parasitic Hymenoptera ; from South Australia.

Mr. R. W. E. TUCKER, Government Entomologist :—25 Cecidomyiidae and 10 larvae, 2 Coccinellidae, 7 Parasitic Hymenoptera, 1 species of Coccidae and 7 Mites ; from Barbados.

UNITED STATES NATIONAL MUSEUM :—33 Parasitic Hymenoptera and 22 cocoons ; from the United States of America.

Mr. G. C. VARLEY :—53 Parasitic Hymenoptera and 29 cocoons ; from England.

Mr. R. VEITCH, Chief Entomologist :—5 Cecidomyiidae and 10 Coleoptera ; from Queensland, Australia.

VETERINARY & AGRICULTURAL OFFICER :—3 Orthoptera ; from British Somaliland.

Mr. J. VINSON :—12 Coleoptera ; from Mauritius.

Mr. F. WILSON :—4 Diptera, 5 Coleoptera, 31 Parasitic Hymenoptera, 8 Lepidoptera, 2 species of Aphidae, 1 species of Aleurodidae, and 6 other Rhynchota ; from England and France.

Miss J. E. WILSON :—5 Cimicidae ; from England.

Prof. V. V. YAKHONTOV :—3 slides of Thysanoptera ; from Russia.

EGGS OF *FICALBIA MINIMA*, THEO., AND NOTES ON BREEDING HABITS OF THREE SPECIES OF *FICALBIA*.

By M. O. T. IYENGAR,
formerly Medical Entomologist, Travancore.

In this article is recorded the finding of eggs of *Ficalbia* (*Ficalbia*) *minima*, Theo., which were hitherto unknown. A description of these eggs is given and they are compared with eggs of *Mansonioides* which occur in a similar situation.

The eggs of *F. minima* are laid on the lower surface of leaves of *Pistia stratiotes*, a common floating water-plant. These eggs, which were first observed in nature, were proved to be those of *F. minima* by allowing them to hatch and identifying the larvae that developed from them. In a few instances, adult *F. minima* were reared from these larvae. Eggs were also obtained in the laboratory from gravid female mosquitos which were enclosed in jars containing water with a *Pistia* plant floating on it.

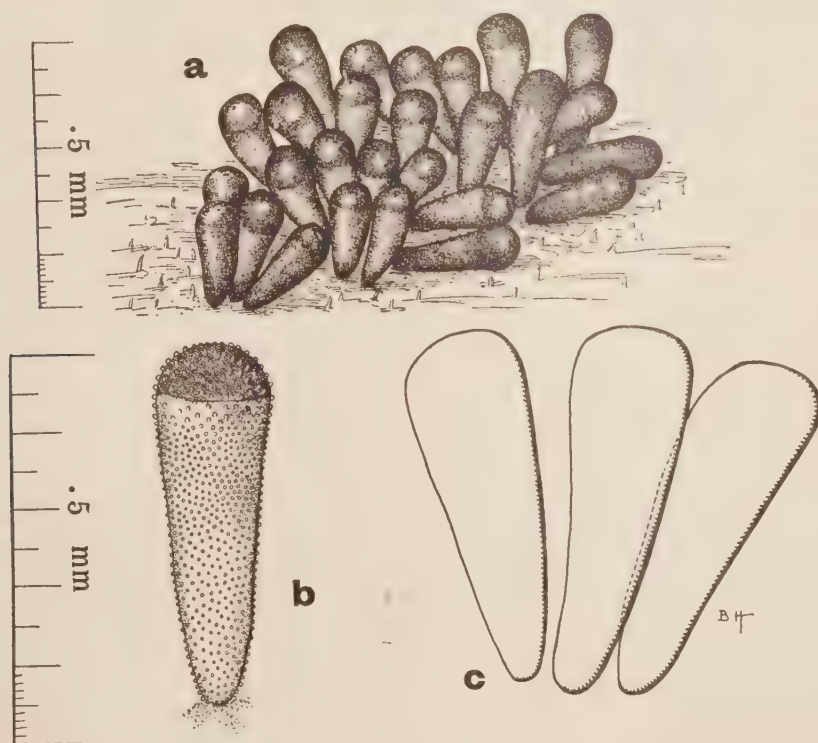


Fig. 1. *Ficalbia minima*, Theo.: a, group of eggs on leaf of *Pistia*; b, side view of egg; c, outline of three eggs.

Eggs of *Ficalbia minima* occur in small groups on the lower surface of leaves of *Pistia*; they have not been observed in any other situation. The egg-cluster is irregular in shape and the eggs are placed without any definite arrangement. The egg-cluster has a varying number of eggs ranging from 15 to 33 (fig. 1, a). The

ON THE IDENTITY OF *LYGUS SIMONYI*, REUT., AND *LYGUS VOSSSELERI*, POPP., IN KENYA AND UGANDA.

By W. E. CHINA, M.A.

Dept. of Entomology, British Museum (Nat. Hist.).

For some years economic entomologists in Kenya and Uganda have recognised two species of Capsids of more than usual importance. *Lygus simonyi*, Reut., was a pest on coffee in Kenya, and *Lygus vosseleri*, Popp., was injurious to cotton in Uganda. The species were originally identified from the keys and descriptions of B. Poppius in his "Die Miriden der Äthiopischen Region" (Acta. Soc. Sci. Fenn. **41**, no. 3, 1912, & **44**, no. 3, 1914). This monograph although indispensable to anyone working on the systematics of the African Capsidae, is on the whole rather unsatisfactory. The illustrations are few and far between, the genera are often based on relative and overlapping characters and the specific differentiations are vague. It is not surprising therefore that the original determination of the coffee Capsid now proves to be incorrect. Thanks to the courtesy of Dr. Richard Frey, of the University Zoological Museum, Helsingfors, and Dr. Max Beier, of the Natural History Museum, Vienna, I have now been able to examine type material of these two species.

Lygus vosseleri, Popp.

Lygus vosseleri, Hargreaves, Rep. Dept. Agric. Uganda, 1932, pt. 2, pp. 50-54, Entebbe 1933.

In his key to the African species of *Lygus* (op. cit.), Poppius separates his new species *L. vosseleri* from *L. simonyi*, Reut., as follows:—

Pronotum and hemielytra with dark markings—*L. simonyi*, Reut.

The whole upper side of uniform colour, only the apex of cuneus black—*L. vosseleri*, n. sp.

It is true that in his description Reuter writes "fascia at apex of corium and inner angle of cuneus fuscous" but he adds "sometimes absent" and in the type material is a specimen entirely without dark markings except for the black apex of the cuneus. *Lygus simonyi* is in fact a variable species extending as it does over the whole of the great African savannah country, from Cape Town in the south to Abyssinia and Arabia in the north and Portuguese Guinea in the west. It is also recorded from Madagascar. An examination of the type material of *L. simonyi*, Reut., 1903, and *L. vosseleri*, Popp., 1912, at once revealed the fact that these two species were identical.

The genitalia were studied and found to correspond.

Reuter gives the type locality as Aden and says that the material is in the Vienna Museum (Mus. Vindob.) but Poppius writes "Aden xii, 1898, O. Simony (Mus. Paris)."

It is therefore possible that Poppius did not see the original type material.

The cotton Capsid of Uganda hitherto known as *Lygus vosseleri*, Popp., must therefore in future be called *Lygus simonyi*, Reut.

Lygus simonyi, Le Pelley.

The well-known coffee Capsid of Kenya is not the true *Lygus simonyi*, Reuter, which, as has just been shown, is identical with the cotton Capsid, *Lygus vosseleri*, Popp. The coffee species thus remains without a name and as it appears to be a new species, is herewith described.

***Lygus coffeae*, sp. nov.**

Lygus simonyi, Le Pelley, nec Reut., Bull. Ent. Res., **23**, pt. 1, pp. 85-99, figs. 1 & 2, 1932.

Colour : Head shining yellow, eyes black, clypeus, juga and lora dark fuscous ; rostrum pale yellow, extreme base reddish brown, apex black ; antennae red, apex of second segment black, third and fourth segments fuscous with bases white. Pronotum shining golden yellow with a slight reddish brown suffusion anteriorly behind each eye sometimes extending over disc. Scutellum shining opaque pale yellow. Hemelytra pale shining translucent yellow, the whole of clavus and the inner basal angle of cuneus suffused with fuscous ; a small dark fuscous or black spot on middle of apical margin of embolium extending slightly on to base of cuneus and the extreme apex of cuneus dark fuscous to black ; membrane infusate with some paler areas in region of basal cells and at costal margin ; veins dark brown except towards apex of cuneus. Coxae trochanters and femora pale yellow, the apices of femora mottled with red or brown ; tibiae red or reddish brown with black bristles ; tarsi pale fuscous. Pleura and venter pale yellow, ostiolar peritreme whitish. Dorsum in male scarlet.

Structure : Nearly glabrous but with a pale short depressed pubescence on venter. Punctuation of pronotum and hemelytra practically obsolete. Head strongly deflexed seen from front, somewhat broader than long, seen from side twice as high as long ; the vertex posteriorly finely carinate, one-half wider (♂) than the diameter of an eye (27 : 18) obscurely delimited from feebly prominent clypeus ; rostrum extending to apices of hind coxae, the first segment extending to apex of xyphus ; antennae arising about one-third of length of eye from apex of eye ; relative lengths of segments 43 : 110 : 83 : 50, the second segment only very slightly shorter than basal margin of pronotum. Pronotum more than one-half as long as broad at base (70 : 115), the latter more than twice as wide as anterior margin ; sides almost straight ; anterior collar fine, barely as wide as second antennal segment, covered at sides by eyes ; calli flat, almost obsolete ; disc strongly convex, smooth, shining, almost impunctate ; posterior margin strongly convex. Scutellum strongly convex, faintly wrinkled, equilateral. Hemelytra much longer than abdomen, feebly rugosely punctate, the embolium narrow, cuneal fracture distinct, costal margin of cuneus convex or projecting more apically than posteriorly. Tibial bristles short, not longer than diameter of tibia ; first tarsal segment slightly shorter than second, the third longer than second. Total length ♂ 5.5 mm. breadth across humeral angles 1.8 mm.

Reference should be made to my figure (fig. 1) illustrating Le Pelley's paper referred to at the beginning of this description.

Habitat : KENYA COLONY, Kiambu, numerous specimens (in spirit) "feeding on young coffee plants," 2.vi.1930 (R. H. Le Pelley). All these specimens are rather teneral and shrivelled.

Allied to *L. neavei*, Popp., but smaller and differs in reduced fuscous colour pattern and much finer and more scattered punctuation.

The confusion between these two species is made worse by the fact that there exists in Kenya a third species of *Lygus* which has been taken on coffee by Mr. F. R. Notley (1932). This species is very similar in appearance to the true *L. simonyi*, Reut., and might easily be mistaken for a dark form of that species. The clavus, corium and inner angle of the cuneus are suffused with fuscous, the embolium and outer half of cuneus remaining pallid. The structure of the left hand male genital clasper is, however, quite different from that in *L. simonyi*. It is possible that this is the species which Poppius erroneously regarded as *L. simonyi*, Reut., when he described his *L. vosseleri*. The distribution of *L. simonyi* therefore may not be so extensive as has been supposed. The existence of this species in Kenya may have been responsible for the original confusion in the identification of the coffee Capsid.

NOTES ON *LYGUS SIMONYI*, REUT.* (CAPSIDAE), A COTTON PEST IN UGANDA.

By G. L. R. HANCOCK, M.A., F.R.E.S., F.Z.S.

(PLATE XVII.)

Damage by *Lygus simonyi*, was first noted by Mr. F. W. Hall, Plantation Manager, on the Government Plantation, Kampala. He drew attention to the fact that a number of minute apical buds were becoming black, dying and falling off, and he associated this damage with small Capsid bugs, which later were proved to include *Lygus*. This association was confirmed experimentally in the laboratory by placing some *Lygus* nymphs in bags on seedlings growing in tins, when similar damage to young buds was observed to take place after two or three days. Another form of damage to the cotton plant in the field had been observed for some years previously throughout Uganda; this consisted of the breaking up of the leaves, often near the apex of the plant or the apex of a shoot, and had been tentatively attributed to *Aphis gossypii*. This insect was tested experimentally, using cotton plants growing in a plot on the Plantation in Kampala and protected by a cage made of brass mosquito-gauze, which excluded predators; these plants developed a very heavy *Aphis* infection, the leaves became crinkled and curled downwards at their edges but did not crack. Owing to the shade produced by the cage and the greater humidity of the cage than the natural plot, this experiment could not be considered conclusive, but examination of uncaged plants in the field showed similar damage and no cracking of the leaf. *Lygus* was then (on two occasions) introduced into a similar cage containing two or three cotton plants which were already infested with *Aphis*; brown angular spots became evident on the youngest leaves within three days and, as the plants grew, these leaves cracked and assumed a tattered appearance; a control cage with no *Lygus* did not show this type of damage on either occasion. In the field similar brown spots on young leaves were common, and in most cases the nymphs of *Lygus* could be found sheltering among the neighbouring buds.

In the Sudan, where *Aphis* occurs without *Lygus*, no cracking of the leaves takes place. Bedford (1920) writes:—"As a result of their feeding the leaves tend to become curled and discoloured, which gives the plant a sickly appearance."

More extensive experiments were then conducted using white cotton mosquito-netting instead of wire. In some cases the *Lygus* died and the total number of insects in each cage could not be kept constant. In consequence of this the amount of damage to the plants was inevitably variable. The plants were caged when 14 inches high and examined when 40 inches high (some of the plants having grown to the top of the cage). *Lygus* was introduced into eight cages and eight were kept as controls; on two of the plants in the former category no feeding was observed, but on six feeding took place in varying amounts. The following figures were obtained on examining the plants (see Hargreaves, 1933).

* The correct name of the *Lygus* found on cotton in Uganda has been shown by Mr. W. E. China (see the preceding paper) to be *simonyi*, Reut., and not *vosseleri*, Popp.

Plants with Lygus.

Reference number of cage	Number of nodes	Number of bolls and buds*
1	2	3
2	24	6
3	19	6
4	36	2
6	42	15
12	17	2
Average	26.7	5.7

* Excluding minute buds hidden in apices of branches.

Plants with no feeding.

Reference number of cage	Number of nodes	Number of bolls and buds*
16	54	35
8	36	29

* Excluding minute buds hidden in apices of branches.

Controls.

Reference number of cage	Number of nodes	Number of bolls and buds*
5	16	10
7	18	12
9	51	44
10	45	43
11	25	19
13	41	41
14	41	37
15	36	19
Average	34.1	28.1

* Excluding minute buds hidden in apices of branches.

From the above table there can be no doubt of the correctness of the attribution of loss of crop to *Lygus*. In the series of controls the number of bolls and buds per plant was in no case less than 10 and had an average of 28.1, while in the series of plants on which *Lygus* was confined (leaving out of account the two cases in



Fig. 1.



Fig. 2.



Fig. 3



Fig. 4. John Dale Sons & Danielsson, Ltd. London

Fig. 1. Cotton plant showing damage by *Lygus* when introduced into a cage covering the plant.

Fig. 2. A control plant in the same experiment.

Fig. 3. A spray of cotton leaves showing damage by *Lygus*.

Fig. 4. Young shed bolls showing damage by *Lygus*.

which no feeding took place) the number of buds and bolls only exceeded 6 in one instance and had an average of 5.7. This result was produced by a Capsid population which never exceeded 10 and, owing to frequent deaths, was usually of the order of 3-4 per plant.

As a result of these experiments, yet another form of damage became attributable to *Lygus*; this is a repression of the growth of the branches. This is particularly well shown in the case of plants 12 and 13 (Plate XVII), which were growing side by side in that part of the plot where the growth of the plants (not all of which were used in the experiment) was best; but it was exhibited in greater or lesser degree by all the plants used.

The damage to the leaves is shown in greater detail on Plate XVII, fig. 3. In the early stages it takes the form of small green angular patches on the very young leaves; these patches rapidly became brown and dry, and the tattered appearance of the plant is due to breaking of the tissues round the dead patches as the leaf grows. It is significant to note that there is a very close similarity between the damage caused to cotton-leaves by *Lygus simonyi* and that done to the leaves of currant by *L. pabulinus* in Europe (Petherbridge & Thorpe, 1928).

A further effect of *Lygus*, which is not brought out very clearly by these results, is a reduction in the actual number of nodes. The difference in average number of nodes in this experiment is not significant, but from field observations the writer is convinced that this is an important effect of attack by *Lygus*.

It must be admitted that there are physiological causes which may prevent the growth of a perfect plant and that there is considerable variation in habit between individual cotton plants, though the less desirable variations are steadily being eliminated by selection.

During the 1934-35 cotton season, varieties derived from a parent known as U₄ and designated SP₁₃, SP₂₀, SP₂₁, and SP₄₈ have not only shown some resistance to *Lygus* attack but also, by their habit and rate of growth, have been able to avoid, to a moderate degree, damage by *Lygus*.

It has been suggested that "*Lygus*-damage" is a purely physiological phenomenon or alternatively that it is caused by *Aphis*. In view of the experiments and observations detailed above and of Bedford's observations in the Sudan, where *Lygus* and this particular type of damage are both absent, both these hypotheses must be rejected.

It is extremely difficult to ascertain what are the factors which influence the amount of damage done by *Lygus* to the cotton plant, but the observations given below may indicate some of them. The severest damage has been observed in Kampala during a very wet season (which type of weather appears in itself to encourage a tall and rather lanky plant) and in the Siroko Valley under Mount Elgon in a very wet year.

The condition of the soil has also been observed to influence the amount of damage; at the experiment farm at Bukalasa in the 1929-30 cotton season one plot (on the model native farm) was nearly free from damage, while a contiguous plot of the same variety planted at the same time (together with all the rest of the main blocks of the Government Farm) showed serious damage to the plants. The only difference between the plots which was noticed was a slightly more gravelly soil on the healthy plot.

During the season (1933-34) the writer was shown by Mr. G. T. Philpott plots in Bunyoro on various soils; in those on light soil on the top of the eastern escarpment of the Lake Albert branch of the Rift Valley, the plants, though rather small, showed excellent growth, and Mr. Philpott had observed the almost complete absence of *Lygus*: on the government plots at Bulindi, where the soil was much heavier and the rainfall higher, the plants had suffered serious damage when young. These plots had been deeply cultivated for a preceding crop and suffered more damage

than neighbouring plots where cultivation was less deep. It was remarkable that, while in the native plots the plants were smaller and the crop mostly harvested, in the government plots the plants were larger and had apparently succeeded in growing away from the *Lygus*. The plants in these latter plots were producing a larger, but later, crop than those in the less deeply cultivated plots.

Mr. P. Chandler informs the writer that plants growing close to the base of large termite hills in Teso (Eastern Province of Uganda) never suffer severe *Lygus* damage but exhibit unusually healthy growth. This is not, however, true of plants growing on land where a termitarium has been destroyed and the material scattered on the surface of the ground. The soil in the neighbourhood of a standing termitarium is better drained and better aerated than the surrounding areas.

The observations detailed above indicate some correlation with excessive moisture, either by way of high rainfall or by way of poor drainage. On the other hand, a hill-side plot on the Kampala Government Plantation suffered far more damage from *Lygus* than a plot in the valley in the same plantation and on the edge of a swamp, both plots being planted simultaneously. Not much reliance can, however, be placed on this observation; the soil of the hillside plot was much poorer than that of the plot in the valley and many of the plants in the upper plot failed, the majority of the survivors being in the lower part of the plot.*

In order to ascertain whether *Lygus* was able to cause shedding of the bolls a number of nymphs were placed singly on young bolls in small bags made of cotton mosquito-netting. In the first experiment the majority of the bolls were shed, but owing to an oversight bags were not put on most of the control plants, so that the experiment was uncontrolled. This experiment was done early in the season; the second experiment had to be begun in dry weather and, though considerable shedding took place, a number of the bolls remained on the plants although many were badly cracked.

The following year the experiment was repeated during rainy weather and gave results similar to the first (uncontrolled) experiment.

The following figures were obtained:—

	Bolls on which nymph was enclosed							Controls				Percentage of bolls unlikely to produce crop
	Number of bolls	Bolls shed showing punctures	Bolls cracked, crop unlikely, not shed	Bolls punctured, not shed, crop probable	Bolls not shed on which insects apparently failed to feed	Bolls shed but no puncture	Percentage of bolls unlikely to produce crop	Number of bolls	Bolls not shed and no feeding	Bolls shed	Bolls shed other cause	
December 1929 (dry weather)...	51	16	13	7	15	0	57	49*	30	10(a)	3	27
December 1930 (wet weather)...	59	45	0	3	9	2	80	53*	37	14(b)	2	30

* During the season 1934–35 extensive observations have been made on the effect of soil and climate on *Lygus* attack. There does not as yet appear to be any simple correlation between these factors and *Lygus* damage, but there are indications that factors which produce much succulent vegetative growth are correlated with a more severe attack. The matter is, however, still under investigation.

* As the number of control bags collected was fewer than that of those with bugs inside, it is possible that one or two were omitted, it is also possible that some may have fallen off and been washed away.

(a) Two of these showed extraneous feeding by *Lygus*, possibly through the bag.

(b) Four of these showed marks similar to damage by *Lygus*.

The results of the above two experiments (leaving out of account the uncontrolled experiment which tends to confirm them) are highly significant and leave no room for doubt that *Lygus* causes shedding of the bolls. They also gave much information as to the type of lesions caused by this insect and associated with the shedding. These are illustrated on Plate XVII, fig. 4. The bolls show small black or brown spots, often coalescing to form slightly sunken pits. The cracking of the bolls referred to in the table appears to be due to unequal growth resulting in splitting at the inter-septal groove; there seems to be no doubt that in this instance it was caused by the sucking of *Lygus*, but it appears also to result from the attacks of other sucking insects.

Field observations on the causes of boll-shedding were being carried out on the same plantation simultaneously with the experiments detailed above, but on a different plot; the figures of natural shedding for the first two weeks of December 1929 and December 1930 (*i.e.* the periods of the experiments) are of interest as giving the percentage of bolls shed in the field which showed damage due to *Lygus*. The observations in 1929 were on the bolls shed into the space between rows totalling 80 plants (assumed to equal the shedding from 40 plants): the number of shed bolls which showed *Lygus* punctures was 21 (35.5 per cent.), 6 showed bollworm damage, and 32 were shed for no ascertainable reason. In 1930 the observations were on the bolls shed from 30 plants: the number of shed bolls showing *Lygus* punctures was 45 (48.9 per cent.), 5 showed bollworm damage, and 42 were shed for no ascertainable reason.

Damage to cotton buds somewhat resembling that caused by *Lygus elisus* in America (McGregor, 1927) has been observed in Uganda, but bagging of small buds is impracticable; so far no observations have been made on bud-shedding in cages with and without *Lygus*, which would appear to be the only way of proving whether the small spots found on the sides of the buds are due to this insect.

Alternative Food-plants.—Besides cotton, *Lygus* has been found on *Vigna catjang*, on which it was first discovered by Mr. P. Chandler, who also noted the fact that the damage to the leaves of this plant was not unlike that caused to cotton; such damage to *Vigna* appears to be uncommon. Adults resembling *L. simonyi* have been found on *Phaseolus vulgaris*, *Cajanus indicus*, *Andropogon sorghum* and *Eleusine* sp. Nymphs from the last-named transferred to cotton produced typical damage to the leaf buds. The possibility of reducing the population of *Lygus* on cotton by the control of these other crops is under investigation, as well as the possibility of this insect being able to breed on other plants.

Parasites.—On only one occasion has a parasite of this species been found, so that the practical value of these insects appears to be small. The insect was a small Braconid (*Euphorus* sp.) bred from a nymph.

Life-history.—It is only recently that it has been possible to find the eggs of *Lygus*. These were laid in the laboratory in the succulent petiole of a very young *Vigna* leaf. The period from egg to adult was 14 days.

Estimations of Damage caused to Cotton in Uganda by *Lygus* and other Pests.

(a) Observations on experimental plots.

Four series of observations to ascertain the amount of shedding of bolls and buds, together with the damage caused by *Dysdercus* spp., were carried out in Kampala. In the first two series scattered plants were selected and the buds and bolls which fell from them were collected daily, a mark being made on a plan of each plant as a check on whether the bud was actually from the observation-plant or blown from a neighbouring plant. This method was found to be difficult to apply when using such native assistance as was available at the time. Two further sets of observations were therefore made by collecting the shed bolls and buds in

wire trays; in the first instance the trays were placed between the rows of plants, while in the second they were placed on each side of each plant so that collections were made from complete rows instead of from one side of one row and one side of another. By the first method (collecting from selected plants) the number of minute shed buds recorded was far less than by collecting in wire trays. This is not considered to invalidate the observations to any serious degree because later work showed that the direct damage to the bolls is apparently of far greater importance than that to the buds.

TABLE I.

Analysis of bolls and buds shed from 60 plants on Kampala Plantation (1928-29) and of the residual crop.

Cause of shedding	Buds	Bolls	Notes
Unknown	571	117	
<i>Lygus</i>	—	337	
<i>Earias</i> spp.	236	443	Mostly <i>Earias biplaga</i> , a few <i>E. insulana</i>
<i>Heliothis obsoleta</i> ...	25	11	The cause of damage is only attributed to <i>Heliothis</i> when this was certain. A few buds and bolls were recorded under <i>Earias</i> may have been damaged by <i>Heliothis</i> .
<i>Anomis flava</i>	2	nil	
Rotten (cause not ascertained)	—	11	
Mature bolls			
Damaged by <i>Earias</i> spp.		83	
Damaged by <i>Argyroplote leucotreta</i>		2	Damage by <i>Argyroplote</i> was probably somewhat higher, figures being included under <i>Earias</i> . The two recorded here were the only two certainly damaged by <i>Argyroplote</i>
Damage by internal disease mostly associated with bug punctures		43	
Completely rotten ...		5	
Green, remaining on plants at time of uprooting and not examined		70	
Bolls harvested		583	
Percentage damaged ...		11.5	Omitting the 70 unexamined

It is clear from the series of observations recorded in Tables I and II that the number of small buds found by collecting below mapped plants is very small compared with the number which are probably actually shed. This tends to exaggerate the proportion of shedding due to bollworms, since the shedding of only a very small proportion of these small buds can be attributed to this cause. The damage by bollworms to buds between 12 and 24 mm. in diameter is of much more importance than that to the smaller buds, since these larger buds are less likely to be shed from

TABLE II.
Analysis of shedding of bolls and buds and of the crop harvested on Kampala Plantation (1929-30 & 1930-31).

Cause of shedding	Size of buds					Size of bolls					Notes	
	0-5 mm.	5-8 mm.	8-12 mm.	12-16 mm.	16-24 mm.	24+ mm.	0-8 mm.	8-12 mm.	12-16 mm.	16-24 mm.		24+ mm.
1929-30 (a)												Shed from 48 mapped plants
Unknown	531			456				430	89		
Bollworm*	...	5			189			48	28			
Lygus		Not proved				140		14			
1929-30 (b)												Collected between rows containing 80 plants. Assumed shedding from 40 plants
Unknown	2,280	619	305	222	33	173	84	25	7	1	
Bollworm	1	4	18	48	39	39	17	10	12	1	
Lygus			Not proved			16	39	9	0	0	
1930-31												Collected from 30 plants
Unknown	1,144	269	152	96	19	186	119	28	6	1	
Bollworm	12	15	21	10	19	24	23	8	2	0	
Lygus			Not proved			113	127	14	5	0	
Bolls harvested												
		Clean	Stained, rotten and dried up			Percentage stained, etc.			Notes.			
1929-30 (a)	...	258	173			40.1						
1929-30 (b)	...	97	132			58.0			Dried bolls not harvested			
1930-31	271	47			14.7						

* Almost all either *Earias biplaga* or *E. insulana*.

"physiological causes"; the percentage of these larger buds, the shedding of which was attributable to bollworms, was 31·7. As mentioned above, there is no proof as to whether *Lygus* is responsible for any shedding of buds.

The damage by *Lygus* to young bolls is shown to be considerable by the results tabulated below :—

Observations	Shed from <i>Lygus</i>	Mature bolls	Lost from other causes	Total	Per cent. loss from <i>Lygus</i>
1928-29 ...	337	786	1,184	2,307	14·5
1929-30 (a)	154	431	595	1,180	13·9
1929-30 (b)	64	229	369	662	9·6
1930-31 ...	254	318	398	970	26·2

(a) Collected from mapped plants. (b) Collected in wire trays.

There are many errors involved in the method employed, which cannot be estimated, and these render the above figures more or less an approximation: damage by *Lygus* is difficult to estimate when the fallen bolls have dried up, since the punctures are not easy to see; these bolls are often recorded as shed from an unknown cause. Indirect loss of bolls by shedding, due to the sucking of the leaves by *Lygus*, is another factor which cannot be estimated. When the season at which boll-shedding occurs is considered, it is clear that damage from *Lygus* affects the earlier bolls to a far greater extent than the later ones; it is the early bolls which form the main crop and which (when mature) are less likely to suffer damage from other insects, and this damage is therefore more serious than would appear from the figures. The greatest potential error is due to our lack of knowledge as to the physiological reactions of the plant to insect attack; we do not even know in which direction these are likely to influence the figures.

A further attempt to estimate damage has been made by spraying some plants and not others. In most cases results have been negative, as either there has been no diminution in the damage or the control plots have been free from attack. During the season 1933-34 Mr. C. G. Hansford kindly carried out a spraying experiment at Serere in the Eastern Province. He sprayed only the tips of the shoots, where *Lygus* nymphs are most commonly found. Though he found that there was still some damage apparent on the plants in the sprayed plots, this was considerably less than on the unsprayed ones. The yield of the sprayed plots exceeded that of the unsprayed plots by 25 per cent. and was statistically significant. Since some damage occurred in the sprayed plots, the actual loss of crop must have been somewhat greater than his results indicate, and it is possible that the damage prevented by spraying was rather that caused to the vegetative parts of the plant than that to the bolls, since the bolls were not sprayed and therefore any reduction of boll-shedding could only have been due to the reduction of the total *Lygus* population; further, the season was particularly dry, which (as indicated above) is not favourable to maximum boll-shedding due to the sucking of *Lygus*. These observations indicate that both in Kampala and at Serere the total loss of crop from *Lygus* is likely to be in the region of 25 per cent. of the number of bolls which reach maturity, but it must be remembered that the spraying may have helped the plants by reducing other insect pests besides *Lygus*.

(b) *Examinations of native plots.*

Some idea of the losses caused by *Lygus* to native-grown cotton may be obtained either by counting the number of *Lygus* present in the plots or by collecting samples

of the shed bolls and examining them for *Lygus*-punctures. The first method is open to the objection that *Lygus* is a difficult insect to find, and to the further objection that the amount of damage caused by a given number of *Lygus* appears to vary with the climatic conditions; the second method has the defect that boll-shedding is not the only form of damage caused by this insect and also that injured bolls often remain on the plant (especially in dry weather) and are therefore not included in the survey.

A series of counts of *Lygus* were made in the Eastern Province during January 1931 and in Buganda during December 1931, and these can be compared with the counts which were made on experimental plots in Kampala to estimate the seasonal prevalence of *Lygus*. A very grave error is, however, at once obvious: cotton plants vary very greatly in size, not only in different plots (owing to planting at different times, and to differences in climate, soil, cultivation, etc.), but also within the same plot, and a large plant will presumably suffer a smaller proportionate amount of damage from one *Lygus* than will a small one. The observations in the Eastern Province were made towards the end of the season, and therefore almost certainly at a time when the incidence of *Lygus* had declined considerably from its maximum. The cotton-season in the Eastern Province is earlier than in Buganda so that the figures obtained from the former area should be compared with those obtained at Kampala in February rather than those obtained in January.

The average numbers of *Lygus* counted on ten plants from each plot in Kampala in January (27 observations) was 6.2, in February (24 observations) 3.1; in another portion of Buganda in December 1931 (16 observations) 3.6; in the Eastern Province in January (71 observations*) 2.8. The variation in the numbers of *Lygus* found in different plots was very great, the total numbers per ten plants ranging from 0 to 34 in the Eastern Province and from 0 to 11 in Buganda. The plots examined at Kampala were planted on 1st August and the other plots in Buganda at about the same time; those in the Eastern Province were mostly planted in July or August. The ten plants examined were selected at random and it was rarely possible to correlate the numbers of *Lygus* present with the amount of apparent damage in the plots, nor were plots in which no *Lygus* were found necessarily free from damage by this insect. *Lygus* was not obtained in 35 of the 71 plots examined in the Eastern Province, nor on 2 of the 16 plots in Buganda; it is unfortunate that the latter sample was such a small one and that it was obtained from only one small part of one district.

If the number of bolls and buds is an indication of the available food (*i.e.* if at this period the bug prefers bolls to leaves, a point on which there is no evidence either way) then the Buganda figure should be divided by 3.5, since the average number of bolls and large buds per plant was $3\frac{1}{2}$ times as great on the plants in Buganda as those in the Eastern Province; in addition, the plants in the Buganda samples were considerably larger, on the average, than those examined in the Eastern Province.

The writer feels that too much emphasis should not be put on the above figures, although they were obtained with great care; they at least prove that *Lygus* occurs almost as commonly on native-grown cotton as on cotton in the experimental plots.

Summary.

Lygus simonyi has been found to cause serious damage to cotton in Uganda, by sucking the young leaves and apical buds, by retarding the growth of the branches, and by sucking the young bolls.

*Some of the plots visited in the Eastern Province were too old and the plants too dry to support many *Lygus*; such plots were not examined. None of the plots in Buganda had reached this stage.

There are indications that soil and climatic factors are of importance in controlling this insect; excessive succulence of the plant appears to be one factor associated with severe damage.

Acknowledgments.

The writer wishes to express his thanks to Mr. H. Hargreaves, Government Entomologist, under whom the above work was carried out. Also to Mr. G. H. E. Hopkins for assistance in the preparation of this paper and to Messrs. Philpott, Chandler and Hall, for information obtained by them in the field.

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NOTES ON THE BIONOMICS OF *GLOSSINA SWYNNERTONI*, AUSTEN.

By H. M. LLOYD, A.R.C.S.

12

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I. INTRODUCTION.

This paper is the outcome of observations made from December 1930 to July 1932 when the writer was stationed at Old Shinyanga, which is situated near the eastern edge of the Shinyanga fly-belt. The country is just over four thousand feet above sea-level and lies about three and a half degrees south of the equator.

The Shinyanga fly-belt is isolated from the main *G. swynnertoni* fly-belt by cultivation steppe and mbuga. It is progressively diminishing in size owing to the reclamation measures that are eating into it from the east (Swynnerton 1925). Until recently *G. swynnertoni* had not been found outside Tanganyika Territory, its general distribution having already been given by Swynnerton (1923). Since then the main fly-belt has been shown to extend northward beyond Ikoma, on the east of Lake Victoria, to just beyond the Kenya border. Its eastern section extends from Kisese northwards through Mbugwe towards Arusha and thence towards Moshi. Specimens have also been caught in the Buhungukira chiefdom, which lies south of Lake Victoria. The fly-belt here is for practical purposes continuous with that of Shinyanga.

The Buhungukira area is very interesting, in that *G. swynnertoni* occurs there in some numbers with *G. morsitans*. Normally this does not happen, *G. morsitans* usually being found in country dominated by *Berlinia globiflora* and *Brachystegia* spp., while *G. swynnertoni* is associated with vegetation of an entirely different type, a description of which will be found below.

Some of the *G. morsitans* from Buhungukira have been found to differ morphologically from typical specimens. These abnormal specimens may be merely hybrids, such as may yet be found on any considerable *morsitans-swynnertoni* overlap, since Dr. J. F. Corson of the Trypanosomiasis Research Institute at Tinde, Tanganyika, has succeeded in crossing *G. morsitans* with *G. swynnertoni*. Crosses have also been obtained (by Mr. W. H. Potts) with *G. pallidipes*.

Though *G. swynnertoni* does not occupy so huge an area in East Africa as does *G. morsitans*, economically it is very important. Before reclamation measures were carried out in Shinyanga, it threatened to overrun all the grazing grounds of the Sukuma tribe (Swynnerton 1925). Further it is a vector of human sleeping sickness, an area affected by which disease, conveyed by this fly, has been described by Swynnerton (1923). In 1933 a further outbreak of this disease took place near Mkalama, necessitating large-scale operations to prevent its further spread into neighbouring fly-belts.

The writer desires to thank Mr. W. H. Potts, Senior Entomologist, and Dr. C. H. N. Jackson, Survey Entomologist, both of the Department of Tsetse Research, for the fly data collected by them while they were stationed in Shinyanga and for reading through his manuscript and giving many useful criticisms and suggestions in the arrangement of the paper. The writer is also indebted to Mr. N. H. Vicars-Harris, Assistant Director of the Department, and to Mr. G. W. St. Clair-Thompson, formerly Forest Botanist of the Department, who made the temperature and rainfall observations quoted below. He would also like to thank Mr. B. D. Burt, Survey Botanist of the Tsetse Research Department, for identification of trees. Finally, the writer is also much indebted to Mr. C. F. M. Swynnerton, Director of Tsetse Research, for many helpful suggestions and criticisms.

II. DESCRIPTION OF COUNTRY ROUND SHINYANGA.

1. Climate.

This area is subjected to the eastern monsoon winds so that two definite seasons occur :—

(a) *The rainy season.*—This season lasts from late November or early December until mid or late April, and is divided into the "short rains" and the "long rains" by a period of two or three weeks' drought, the "short dry season," in January or February. The rain may occur in short torrential storms or in more gentle falls lasting for several hours. Days on which rain does not fall are usually sunny and hot. The "short dry season" is usually very hot and cloudless, and the grass becomes very severely wilted—even dry.

(b) *The dry season.*—Rain is absent, excepting one or two light showers. The days are for the most part cloudless and very hot, especially in September and October. For a week or two before the rains break the weather is rather more cloudy and very oppressive. There is a strong easterly or south-easterly wind, which blows steadily up till mid-day, after which time there is only a fitful breeze. During the early part of the dry season (May till August) the nights and early mornings are very cool. The trees are leafless by the end of June or early July and remain so until the break of the rains. The grass is dry enough to burn patchily within three weeks or a month from the commencement of the dry season.

2. Topography.

The country is gently undulating. The rises are very largely granitic, commonly with under-lying pseudo-laterite (morram), but some of the eluvial red soils are also derived from schist. They drain into rather open "hard-pan" valleys, in which the soil surface comes close to beds of an impervious limey concrete or the morram. When it rains the water lies about where depressions occur. This hard pan is often overlaid in patches by a clogging alluvial "black cotton soil." Rocky granite kopjes are scattered here and there.

3. Vegetation.

This may be divided into four main types, which follow closely the topography : (a) *Commiphora Fischeri* and associated flora, (b) *C. Schimperi* and associates on "hard pan," (c) *Acacia* spp., and (d) open plain.

(a) *Commiphora Fischeri.*—The dominant tree in the country worked is *Commiphora Fischeri* (Burseraceae), and this vegetation type will be referred to below as "*C. Fischeri*." It occurs typically on rises on the red and better-drained granite soils. Other common trees in this type are *Ostryoderris Stuhlmannii*, *Strychnos heterodoxa*, *Commiphora pilosa*, *C. ugensis*, *C. Stuhlmannii*, *Combretum Zeyheri*, *C. splendens*, *Fagara Merkeri*, and *Vitex Hildebrandtii*. Species occurring less commonly are *Pterocarpus Bussei*, *Combretum ternifolium*, *Schrebera kiloneura*,

Boscia sp., *Terminalia sericea*, *Euphorbia bilocularis*, *Azelia cuanzensis*, and *Tamarindus indicus*.

Shrubs which occur and which often form thickets with the trees mentioned above are: *Combretum longispicatum*, *Markhamia lanata*, *M. acuminata*, *Strophanthus Eminii*, *Grewia* spp., *Ormocarpum aromaticum*, *Abrus Schimperi*, and *Acacia pennata*. These thickets are in the main small and evenly scattered throughout the bush. They rarely cover an area exceeding two or three hundred square yards.

TABLE I.
Monthly temperature and rainfall from February 1931 to July 1932.

Month	Screen maximum mean temperature F.	Screen minimum mean temperature F.	Rainfall in millimetres	Seasons
1931				
February	92.06	64.87	47.3	} Long rains
March	86.06	62.74	191.3	
April	85.16	63.95	155.8	
May	85.75	62.48	32.1	} Long dry season
June	85.62	60.65	nil	
July	86.26	61.14	nil	
August	87.20	60.73	nil	
September	90.10	63.33	10.1	
October	92.35	66.27	13.4	} Short rains
November	91.15	66.43	43.8	
December	83.3	63.50	151.8	
1932				
January	86.2	64.2	63.0	} Short dry season
February	82.0	63.0	69.5	
March	81.0	62.4	157.3	} Long rains
April	82.8	63.0	136.5	
May	83.2	62.2	22.5	} Long dry season
June	85.5	59.7	nil	
July	85.0	58.0	nil	

The grass growth of *Hyparrhenia* spp. in this type of bush is good except in the thickets, where it is generally absent. Outside them the average height of the grass is about five feet. Its maximum height in some years is attained about near the end of the "short rains."

(b) *Vegetation on and about hard pan.*—The two dominant trees here are *Lannea humilis* (Anacardiaceae) and *Commiphora Schimperi*; others occurring are *Zizyphus mucronata*, *Boscia* sp., *Randia Taylorii*, *Terminalia Stuhlmannii*, *Acacia usambarensis*,

A. Senegal, *A. spirocarpa*, *A. Bentharii*, *A. mellifera*, *A. Fischeri*, *A. drepanolobium*, and *Albizzia Harveyi*. Thickets composed of the above and the following shrubs occur: *Combretum parvifolium*, *Thylachium africanum*, *Maerua trichophylla*, *Grewia* sp., *Anisolis* sp. (Acanthaceae), *Harrisonia abyssinica*. Small thickets are present, less scattered than in the *C. Fischeri* bush.

Hard-pan areas are usually drained by streams or erosion channels along the banks of which continuous thicket occurs. Big rivers support large trees of *Ficus sycomorus*, *Acacia campylocantha*, *Albizzia brachycalyx* and *Piptadenia Hildebrandtii*.

The grass growth is very poor and patchy and does not exceed a foot in height. Hard-pan patches may extend upwards as arm-like valleys into *C. Fischeri* bush, as mentioned above, in which case they may be anything from a quarter of a mile to several miles in length and from twenty to two hundred yards in width. Hard pan commonly occurs over large areas interspersed with open *Acacia* parkland, where it is often associated with large rivers. In this type of bush and in the preceding type "baobabs" (*Adansonia digitata*) are numerous.

(c) *Acacia Savannah*.—In the Shinyanga district, as worked by the writer, this is usually open savannah wooding with few or no thickets. Patches of hard pan may occur. The following trees are present:—*Acacia spirocarpa*, *A. Bentharii*, *A. usambarensis*, *A. drepanolobium* (on the hard-pan patches), *A. Fischeri*, and *Albizzia Harveyi*. The grass growth is good, being from three to four feet high.

The streams draining hard-pan valleys flow into the small seasonal rivers which pass through *Acacia* savannah. These rivers in some cases drain the open plains.

(d) *Open plains*.—These areas are treeless grasslands occurring on heavy "black cotton" soil and hard pan. During the rains they are largely sodden or submerged, whilst in the dry season they are entirely waterless for miles. Patches of "gall" *Acacia* (*A. drepanolobium*) occur here and there.

4. Evaporation Rate in the several Types.

Fig. 1 shows the evaporation rates in three vegetation types, obtained with Livingston-thon, white, spherical, cup atmometers. The average daily evaporation is given by months in cubic centimetres.

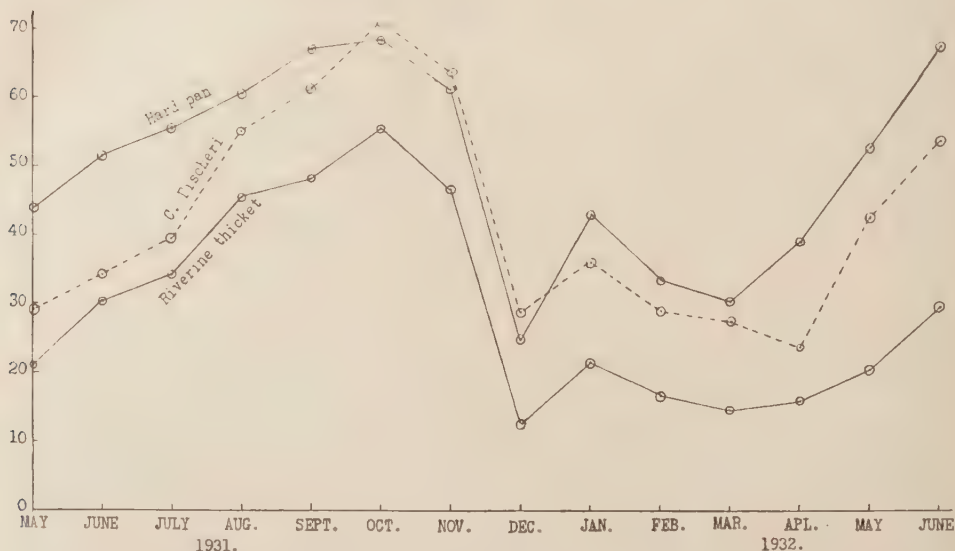


Fig. 1. Mean daily evaporation in cc. in hard pan, *C. Fischeri* and riverine thicket.

The hard pan had the greatest evaporation for most of the year, while the thicket had the least throughout the year. Except for October, November and December, the *C. Fischeri* curve of evaporation follows an intermediate course between the two other curves. All three curves show a continuous rise in evaporation as the "long dry season" progressed. With the first large fall of rain in November there was a drop; and a very large drop took place during the heavy rains of December. The "short dry season" in January 1932 caused a rise, which was followed by a drop in February and March as the "long rains" progressed. Towards the end of the rains in April there was a rise continuing into the "long dry season."

In August 1931 the rise was more pronounced in the *C. Fischeri* than in the hard pan, as at the beginning of that month the bush was burnt, destroying the long grass in the *C. Fischeri* and thus making the conditions in this type of bush and in the hard pan more nearly alike. The most severe conditions obtained were in October when the evaporation in the *C. Fischeri* slightly exceeded that of the hard pan. The evaporation remained greater in the *C. Fischeri* for November and December owing to greater exposure and lack of thickets. As the grass in the *C. Fischeri* grew again the evaporation there became less than in the hard pan.

5. Game.

The game in the Shinyanga district is moderate in numbers. In the first three types of bush mentioned above impala (*Aepyceros melampus suara*, Matschie), giraffe (*Giraffa camelopardalis tippelskirchi*, Matschie), dik-dik (*Rhynchotragus kirki cavendishi*, Thomas), duiker (*Sylvicapra grimmii hindei*, Wroughton), steinbok (*Raphicerus campestris neumanni*, Matschie), and wart-hog (*Phacochaerus africanus aeliani*, Cretzschmar) are all common. Less common are eland (*Taurotragus oryx pattersonianus*, Lydeker), roan antelope (*Hippotragus equinus langheldi*, Matschie), greater kudu (*Strepsiceros strepsiceros bea*, Heller) and zebra (*Equus granti*, De Winton). Of late years, black rhinoceros (*Diceros bicornis*) have been seen and their spoor is more often recorded. Lion, hyaena (both spotted and striped) and leopard occur, and baboons and monkeys (*Cercopithecus pygerythrus*) are common. Of the smaller animals hyraxes, mongooses, jackals and civet cats are common, francolins (*Pternistes rufopictus*, Rchw., *Francolinus sephaena rosvuma*, Grey, and *F. coqui*, Smith) abound and guinea-fowls (*Numida mitrata reichenowi*, O. Grant) are frequently met with. Hares are less common. On the large plains topi (*Dama-liscus korrigum jimela*, Matschie), eland, wildebeest (*Gorgon albobubatus mearnsi*, Heller), Thomson's gazelle (*Gazella thomsoni thomsoni*, Gunther) and ostrich are at times common.

III. THE RELATION OF *G. SWYNNERTONI* TO VARIOUS VEGETATION TYPES.

1. The Hunger and Female Percentage of *G. swynnertoni* in the various Types of Vegetation.

Throughout this paper Dr. C. H. N. Jackson's hunger staging of flies has been used (Jackson 1933). The stages are briefly summarised below.

Hunger stage	Description
I	Flies which have just fed
II	Replete flies which have fed comparatively lately
III	Flies becoming hungry and sometimes willing to feed on man
IV	Hungry flies eager to feed

The mean hunger stage (M.H.S.) evolved by Dr. Jackson for comparing the hunger of flies from place to place or from time to time is utilised.

(a) *C. Fischeri*.—Flies caught with nets in the *C. Fischeri* type of bush are replete, and the percentage of females is very small. Where fly density as a whole is low, exceedingly few flies are taken in the *C. Fischeri* bush.

(b) *Hard pan*.—The hard-pan areas have the greatest apparent density of flies. It may be quite high even when very few flies are being taken from surrounding vegetation of a different type. Here one would expect the fly to be hungry and have a high female percentage, as this type closely resembles the borders of a *G. morsitans* feeding-ground, as described by Jackson (1930). However, when a catch is made the hunger and female percentage of the fly are not high, but are higher than those of the fly in the *C. Fischeri* and slightly higher than those of fly caught in the home of *G. morsitans*.

(c) *Acacia community*.—In the *Acacia* savannah described, the female percentage and mean hunger stage are high and density is low, unless there is much hard pan admixture.

(d) *Open plains*.—The fly in the bordering open plains behaves as in a typical feeding-ground, that is to say, the flies are hungry and the female percentage high.

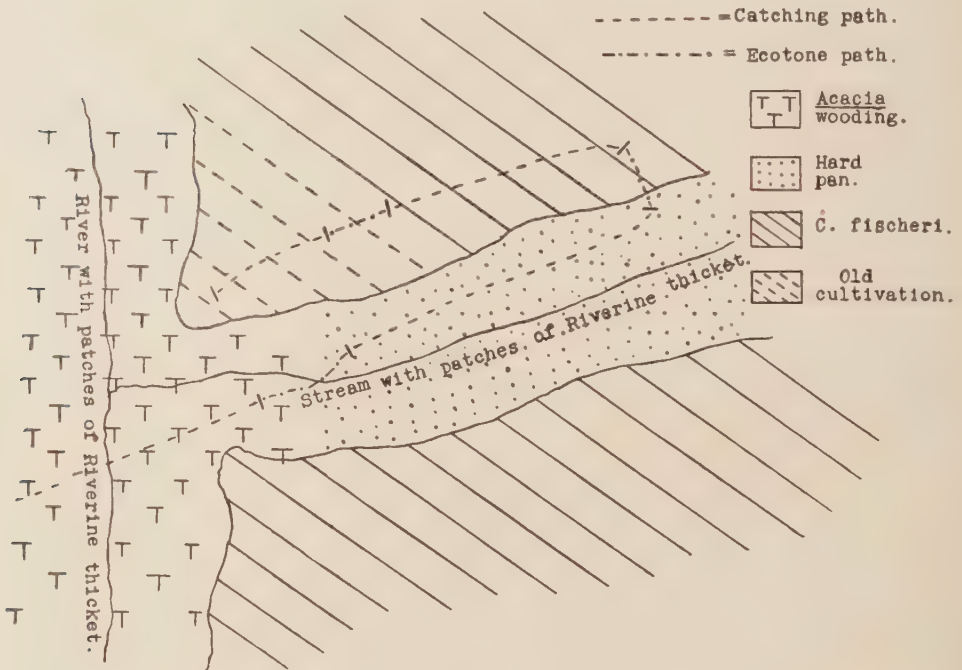


Fig. 2.

2. Experiments to determine the Behaviour of Fly in different Vegetation Types.

(a) *Hard-pan areas and feeding-grounds.*

Jackson found that *G. swynnertoni* was using certain treeless areas and roads as feeding-grounds (1931). However, it was not determined where flies were feeding when open areas, roads or other feeding-grounds were distant. Accordingly in

January 1931 an experiment was designed to investigate the problem and to elucidate the behaviour of the fly in *C. Fischeri* bush bordering the other types.

A piece of country was chosen where the heads of two hard-pan valleys converge on a neck of *C. Fischeri* bush in which *Combretum Zeyheri* and *C. splendens* are dominant. A blazed trail, passing up one valley over the *C. Fischeri* rise and down the opposite valley, was followed daily, regular halts being made to catch flies. The method of marking flies used by Jackson (1930, 1933) was employed. The flies were marked with oil paints to show the locality in which they were taken, the date of capture, and their hunger stage. They were then immediately released. Any flies recaptured by the writer were re-marked on the clock system, which distinguishes individual flies. Any recaptured by fly-boys working independently were killed and recorded. Flies were marked differentially for three areas, namely, the two hard-pan valleys and the *C. Fischeri* bush. At the end of the transect through the first valley following flies were driven away. The ecotone (transitional zone between two types of bush) between the hard pan and the *C. Fischeri* was then crossed for marking to be carried out in the *C. Fischeri*. Halts were made on the transect through the ecotone to capture and to re-mark any marked flies that might still be following. The same routine was also carried out at the end of the *C. Fischeri* transect before proceeding to the second valley. Flies which had been marked on previous days were caught, re-marked and recorded.

Catches were made outside the areas where the marking was done in order to investigate the outward movements of these flies. The experiment was carried out from 9th January to 5th February 1931, flies being marked on 23 days. In all, 1,023 flies were marked; of these only 100 were in the *C. Fischeri* bush, so that no conclusion could be drawn as to the behaviour of *G. swynnertoni* in this type of vegetation. The following flies were marked:—

TABLE II.

Locality	Males	Females	Total	♀♀ percent.	Hunger stages				Mean hunger stage
					IV	III	II	I	
Both hard-pan areas combined	912	11	923	1.2	97	486	308	21	2.76
<i>C. Fischeri</i> ...	100	0	100	0.0	9	43	38	10	2.68

The female percentage and mean hunger stage of both these areas are similar to what would be expected in the home of *G. morsitans*. However, recaptures of marked flies showed that they were not merely using the marking area as a refuge for digesting food and feeding outside. This may be seen from the average number of days taken by flies to re-appear again, since it would be expected that hungrier flies would move away to a feeding-ground sooner than would more replete individuals.

TABLE III.

Locality	Hunger stage				
	I	II	III	IV	
Hard pan ...	2.0	2.2	1.8	1.0	Average period in days between first and second capture
Outside the hard pan ...	3.0	2.8	2.0	—	

Thus it would appear that flies were feeding just as much inside the hard-pan area as outside it, so that it was a feeding-ground as much as a "home." There is no reason to doubt this as giraffe, wart-hog, impala, dik-dik and duiker were continually seen in the hard pan.

(b) *Movement of fly from hard pan to roads.*

From a marking experiment, which however was not designed in the first place to elucidate the feeding habits of *G. swynnertoni*, it would appear that this fly will move from one area of hard pan to another as readily as to a road feeding-ground. That is, its movements are probably haphazard; when in search of food it does not go off in any particular direction. This proposition is not regarded as conclusive, as the number of recaptured flies, though worth consideration, was small. It would be desirable to repeat the experiment on a large scale.

A hard-pan area was divided arbitrarily into two portions, an easterly (A) and a westerly (B); east of A was a road much frequented by foot traffic. Flies were marked differentially to show whether they were originally marked in A or B, or on the road.

Total number of flies marked in A, 294; in B, 178; on the road, 315.

Of the flies marked in A, which was situated between B and the road, the following numbers were recaptured:—Recaptured in A, 29; in B, 7; on the road, 13.

Taking the recaptures of flies marked in A alone.

1. For every 100 flies recaptured in A 700/29 flies were recaptured in B.
2. But 294/178 more flies were caught in A than in B.
3. Therefore there were 294/178 more chances of catching marked flies in A than in B.
4. In order to obtain the recaptures in B in the same ratio as the recaptures in A multiply by 294/178, i.e., $700/29 \times 294/178 = 40$.

Therefore for every 100 flies recaptured in A, 40 were recaptured in B. Relating A and the road in a similar fashion, for every 100 flies recaptured in A, $130/29 \times 294/315 = 42$ flies were taken on the road. That is, the dispersal of flies from A to the east and to the west was equal. If, however, flies were going to the road especially to feed, it would be expected that the movement of flies to the road (eastwards) would be greater than that to the bush on the west.

Of the flies that were marked on the road, for every 100 recaptured there, 161 were recaptured in A. Of the flies marked in B, for every 100 flies recaptured there only 65 were recaptured in A.

If flies were feeding on the road from A—and it was not proved whether they were, as the number of recaptured flies was too small—they were returning to A in preference to remaining on the road. On the other hand, flies from A that fed in B tended to remain there to digest their food rather than to return to homogenous bush to digest it. It is thus possible that flies when in search of food in hard-pan areas move off in any direction; when they encounter an animal in the hard pan they will feed on it and digest their meal in a sheltered spot near by. If they strike a road or other feeding-ground before meeting an animal, they will patrol this until they get a feed, and then retire to less exacting conditions in well sheltered bush.

(c) *Acacia, hard pan and C. Fischeri bush.*

Reconnaissances through thick fly in December 1931 indicated that flies in *C. Fischeri* bush were using hard-pan areas as feeding-grounds; accordingly a marking experiment was carried out to see whether this was so. Besides definite transects through *C. Fischeri* and the hard-pan areas two other transects were demarcated,

one across a valley containing *Acacia spirocarpa* and *A. campylocantha* with a few small thickets, and another through old cultivation covering pseudo-laterite soil on which the bush had partly regenerated.

Flies were marked differentially to show locality of marking, hunger and day of marking. They were re-marked on the clock system.

The *Acacia* country was traversed first, after which, as in the first experiment described, a neutral zone was traversed where no fresh flies were marked; those flies which had followed from the *Acacia* and any fly marked on a previous day, were re-marked. The next transect followed the hard-pan valley, which drained into the *Acacia* valley. Succeeding this was a neutral zone before the *C. Fischeri* bush, the transect of which ran back parallel to the hard-pan transect. Between this and the final transect of old cultivation was another neutral zone (fig. 2).

In all, 3,386 flies were marked on twenty-six days, between 2nd March and 18th April 1932. Particulars are given in Table IV.

TABLE IV.

Transect	Males	Females	Total	♀♀ percent.	Young males	Young females	Young fly percent.	Mean hunger stage	Pregnant female percent.
<i>Acacia</i> ...	383	68	451	15.3	23	23	10.2	3.04	5.9
Hard pan	2,239	163	2,402	6.8	49	60	4.4	2.73	4.8
<i>C. Fischeri</i>	443	14	457	3.1	3	3	1.3	2.38	14.3
Old cultivation	68	8	76	6.5	2	2	5.3	2.64	0.0

Omitting the transect through the old cultivation, where the number of fly taken was small, the three vegetation types—*Acacia*, hard pan and *C. Fischeri*—produced catches in which the female percentage, young fly percentage and mean hunger stage, were all highest in the open *Acacia* woodland and least in *C. Fischeri*.

From these figures the relation of the *C. Fischeri* to hard-pan bush would appear to be that of a home to a feeding-ground, *i.e.*, flies were coming from the *C. Fischeri* bush to feed in the hard pan. This is brought out by the fact that repleter flies marked in the *C. Fischeri* took longer to reach the hard pan than did hungrier individuals.

The average length of time taken from *C. Fischeri* to hard pan was: Stage I, 3.5 days; II, 2.3 days; III, 2 days.

Details of recaptured marked flies:—

Marked in hard pan.

(a) Recaptured in hard pan	...	...	288
(b) Recaptured in <i>C. Fischeri</i>	...	...	23

Marked in *C. Fischeri*.

(a) Recaptured in <i>C. Fischeri</i>	...	...	9
(b) Recaptured in hard pan	...	...	52

Referring to Table IV it will be seen that 2,402/457 more flies were taken in the hard pan than in the *C. Fischeri*. Reducing to the same proportion as on page 446 the recaptures of the flies marked in the hard pan, for every 100 flies recaptured there, $23 \times 100/288 \times 2,402/457 = 42$ flies were recaptured in the *C. Fischeri*.

This means that more flies remained in the hard pan than went to the *C. Fischeri*. Similarly of the flies marked in the *C. Fischeri*, for every 100 recaptured there, $52 \times 100/9 \times 457/2,402 = 95$ were retaken in the hard pan.

That is, movement of flies to and fro within the *C. Fischeri* bush itself was approximately the same as the movement of flies to the hard pan from the *C. Fischeri*; whilst the movement of flies from the hard pan to the *C. Fischeri* was less than the movement of flies in the hard pan itself. Thus, though flies from the *C. Fischeri* bush were feeding in the hard pan, many did not return to the *C. Fischeri* to digest their meal. It would appear from this conclusion that eventually the *C. Fischeri* would become entirely evacuated. However, when the population is large it is maintained by the flies emerging from the pupae deposited there (see page 452). If the population is diminishing, owing to reclamation methods or some other factor, almost complete evacuation may occur, as there are not enough pupae deposited to produce flies to take the place of the flies that have left. The fly may reach such a low density that it will be impossible for the sexes to meet in the *C. Fischeri*. That this may be the case is shown by the paucity of flies in *C. Fischeri* after reclamation methods have been carried out, whilst in the hard pan fly is still fairly common. The odd flies in the *C. Fischeri* no doubt have come in from the hard pan.

Table V describes movements of flies which were captured three or more times. Many flies were taken more than twice; but as sometimes many days elapsed between each recapture, their movements in between could not be surmised, so that they are not cited.

TABLE V.

Re-mark number	Locality	Stage	Days' interval	Remarks
371	<i>C. Fischeri</i> ...	II	—	On becoming hungry goes to hard pan
	Hard pan ...	III	4	
	" ...	III	5	
354	<i>C. Fischeri</i> ...	II	—	
	Hard pan ...	III	2	
	" ...	III	2	
230	<i>C. Fischeri</i> ...	II	—	Fed while in stage III, thus becoming stage I
	Hard pan ...	III	1	
	" ...	I	11	
229	<i>C. Fischeri</i> ...	II	—	
	Hard pan ...	III	1	
	" ...	III	12	
196	Hard pan ...	IV	—	Hungry in hard pan. Feeds and digests in <i>C. Fischeri</i> . Returns to hard pan semi-hungry
	<i>C. Fischeri</i> ...	II	2	
	Hard pan ...	III	6	
78	Hard pan ...	IV	—	
	<i>C. Fischeri</i> ...	II	5	
	Hard pan ...	IV	9	

The first four flies did not return to the *C. Fischeri* after feeding.

Another fly, No. 24, behaved erratically. It was first found as a stage I fly in the hard pan. Five days later it was also taken as a stage I fly in the *C. Fischeri*, and two days after that it was retaken as a stage II fly in the hard pan.

The majority of flies caught more than three times were taken each time in the hard pan and in all stages of hunger, suggesting that hard pan may provide all the requirements of the fly. Many of these recaptures are listed in Table VI.

TABLE VI.

Re-mark number	Locality	Stage	Days' interval	Remarks
14	Hard pan	...	II	—
	"	...	I	3
	"	...	IV	2
19	Hard pan	...	III	—
	"	...	II	3
	"	...	III	1
75	Hard pan	...	I	—
	"	...	III	2
	"	...	IV	1
139	Hard pan	...	I	—
	"	...	II	1
	"	...	I	3
141	Hard pan	...	III	—
	"	...	III	5
	"	...	II	4
	"	...	III	1
207	Hard pan	...	IV	—
	"	...	IV	1
	"	...	III	19
143	Hard pan	...	II	—
	"	...	II	5
	"	...	I	4
	"	...	II	1
	Between hard pan and C. <i>Fischeri</i>	...	I	4
214	Hard pan	...	II	—
	"	...	II	1
	"	...	II	5
291	Hard pan	...	II	—
	"	...	IV	2
	"	...	IV	1
443	Hard pan	...	II	—
	"	...	III	2
	"	...	III	4

Though from Table IV it would appear that the *Acacia* country is used considerably as a feeding-ground by flies in the hard pan, marked flies generally do not support this view.

The hungrier flies marked in the hard pan did not tend to reach the *Acacia* bush appreciably faster than did the less hungry ones.

Average length of time Stage I flies took to reach *Acacia* bush 3 days.

"	"	"	II	"	"	"	2	"
"	"	"	III	"	"	"	3	"
"	"	"	IV	"	"	"	1	"

It would appear that though odd flies which fail to get a feed in the hard pan eventually get a feed in the *Acacia* bush, flies resident in the hard pan usually manage to get a feed there ; further, that the *Acacia* bush, where this experiment was carried out, is capable of supporting a community of tsetse independently of other types of bush, as some small thickets were present where shelter for digestion could be obtained.

Only one marked fly (No. 353) went from the hard pan to the *Acacia*, fed and then returned to the hard pan ; two days later it was found as a stage IV fly in the *Acacia*, where it possibly fed, returning to the hard pan, where it was found five days after as a stage III fly.

Two other cases of *Acacia* flies that probably fed in hard pan are seen in Table VII.

TABLE VII.

Re-mark number	Locality	Stage	Days' interval	Remarks
17	<i>Acacia</i> ...	II	—	Had fed and gone to <i>C. Fischeri</i> .
	<i>C. Fischeri</i> ...	II	5	Had fed and gone to hard pan
	Hard pan ...	II	7	Becoming hungry moved to
	<i>Acacia</i> ...	III	1	<i>Acacia</i>
215	Hard pan ...	III	—	
	Between hard pan and <i>Acacia</i> ...	I	2	
	Hard pan ...	I	12	

Conversely, in Table VIII, we have flies apparently going from the *Acacia* to feed in the hard pan.

TABLE VIII.

Re-mark number	Locality	Stage	Days' interval	Remarks
376	<i>Acacia</i> ...	II	—	Becoming hungry goes to hard pan to feed
	Hard pan ...	III	1	
	„ ...	III	4	Becoming hungry in hard pan
71	<i>Acacia</i> ...	II	—	
	Hard pan ...	III	2	
	<i>Acacia</i> ...	III	6	
55	Hard pan ...	IV	—	Hungry in hard pan
	<i>Acacia</i> ...	II	3	Resting in <i>Acacia</i>
	Hard pan* ...	II	3	
43	<i>Acacia</i> ...	II	—	
	Hard pan ...	I	2	
	<i>C. Fischeri</i> ...	II	13	

* Hard-pan area about a mile beyond hard-pan area of experiment and separated from it by a band of *C. Fischeri*.

Summarising, we come to the following conclusions :—

Commiphora Fischeri bush is favourable for fly to live in, that is, for digestion of food and for breeding (see below—“ Breeding Sites ”). Though game may be

plentiful, the fly may not be able to feed sufficiently often, as the visibility is comparatively poor. Providing that the tsetse, while searching for food in *C. Fischeri*, does not fly round in circles but steers approximately a straight course, it will in time strike a hard-pan patch, if it has not already found food. In the hard pan the game is sufficient and the visibility excellent. Here the fly will hunt for food, and avoid returning to the *C. Fischeri* owing to the poor visibility. Before long it may encounter an animal and feed to repletion. Observation shows that when a tsetse has engorged, it flies off its host to some near shelter, such as a thicket or tree, and there rests. It has been seen above that shelter is plentiful in hard pan, so that a tsetse need not return to *C. Fischeri* to digest its food. If, however, the fly fails to find suitable shelter in hard pan, it may chance to enter the *C. Fischeri*, and obtain better shelter there. It appears from the experiment with marked flies that certain individuals went from the hard pan to feed in the *Acacia* bush. The number of flies doing this possibly was not large, as we seem to have the reverse process going on as well. That both movements were happening is probably because the visibility in the *Acacia* was not appreciably greater owing to the presence of long grass, which is absent from the hard pan. After the grass fires the visibility would be better in the *Acacia*. Many of the flies moreover which fed in the *Acacia* bush or elsewhere would be able to digest their food in the *Acacia*, as in the area chosen a few thickets were present.

The apparent density per boy 100 yards for each transect was obtained from the formula (Nash 1933) :—

				$\frac{100 \times \text{total fly}}{\text{catchers} \times \text{yards} \times \text{days of marking}}$
Transect.				Flies per boy 100 yards.
<i>Acacia</i>	...	...	...	0.9
Hard pan	...	...	...	5.4
<i>C. Fischeri</i>	...	...	...	1.2
Old cultivation	...	...	...	0.4

These figures may be supposed to represent the preference of *G. swynnertoni* for the several types of bush, the hard pan being the most favourable, in that it shows the greatest apparent density.

Summarising, we find that *C. Fischeri* bush, hard pan and *Acacia* bush, are each capable of supporting *G. swynnertoni*, providing that (1) it finds food there; (2) it obtains sufficient shelter to digest its food there.

Roads and open mbugas provide areas for obtaining food when the tsetse have failed to find food in any or all of the three types of bush mentioned above. However, owing to the absence of trees and thickets, roads and open mbugas do not allow digestion and breeding to be carried on there, and cannot support a fly population independently.

(d) Observations on the bush east of Lake Victoria.

Other types of country than the above are infested by *G. swynnertoni*. Thus in the infested *Acacia* bush at Chamliho and Suguti, to the east of the Lake Victoria, where the grass had been burnt some time before, the following conditions were noted during reconnaissances in July 1933. On the high-lying portions where many thickets were present the fly was not hungry, the mean hunger stage being 2.50.

The trees here were *Acacia spirocarpa*, *A. Benthamii*, *A. hebecladoides*, *A. seyal*, *Balanites aegyptiaca*, *Albizia Harveyi*, *Dalbergia melanoxylon*, *Lannea humilis*, *Commiphora Schimperi* and *Boscia caloneura*. The grass was short and the ground burned. Thickets were formed by the above trees with *Acacia pennata*, *Grewia*

bicolor, *Harrisonia abyssinica*, *Sansevieria* sp. and *Aloe* sp. The lower-lying bush was more open, and in the main thicketless, except alongside the water-courses. The chief trees were *Acacia spirocarpa*, *A. Fischeri*, *A. Bentharii*, *A. hebecladoides*, and *A. seyal*, growing on an approach of black alluvium. This type ran up as narrow valleys into the first type of bush described, or occurred as wide stretches flanking the open plain. In these lower-lying areas the fly was hungrier having a mean hunger stage of 3.33. The female percentage was high, 18.15.

No doubt *G. swynnertoni* behaves in the thicket-studded *Acacia* bush as it does in hard pan. It will feed there if it encounters an animal, but if on its search for food it strikes a valley or edge of an open plain it will remain there until food is encountered, and then retire to the more sheltered higher-lying bush to digest its food.

The fly in this region was also abundant in vegetation occurring on red soil at the base of banded ironstone hills. The appearance of the bush differed from hard pan chiefly in having a more abundant grass growth. The trees were *Acacia Bentharii*, *Balanites aegyptiaca*, *Fagara merkeri*, *Lonchocarpus capassa*, *Combretum splendens*, *Lannea fulva*, *Commiphora pilosa*, *C. Schimperi*, *Albizzia brachycalyx*, *Tamarindus indicus*, *Dalbergia melanoxylon* and *Boscia caloneura*. Small thickets were common, and were composed of *Grewia bicolor*, *Dichrostachys glomerata*, *Rhus* sp., *Acacia pennata*, and *Harrisonia abyssinica*. The fly here was not hungry, having a mean hunger stage of 3.06. The female percentage was 9.5. In this type of bush as with the higher-lying *Acacia* bush no doubt the fly behaves as in hard pan.

3. Breeding Sites of *G. swynnertoni*.

Swynnerton (1923) records *G. swynnertoni* breeding under thickets and at the bases of kopjes. Dr. Jackson in 1927 found *G. swynnertoni* breeding also in an open type of bush consisting mainly of *Dalbergia melanoxylon*, pupae occurring at the bases of the trees. In 1933 during the dry season he took one unemerged pupa from under a fallen *Acacia hebecladoides* on "black cotton soil." Pupae would scarcely survive in such a situation during the rains, owing to the waterlogging of the soil, a condition lethal to tsetse pupae (Nash 1933).

However, wherever there is a sufficient shelter *G. swynnertoni* would seem capable of breeding, and in Shinyanga it was found by the writer to be breeding in similar positions to those cited above. Where a fallen log, a leaning tree or a rock shelter occurred in a thicket, pupae were taken under these objects in greater numbers than in the rest of the thicket; under overhanging rocks they were found only round the bases of kopjes, never high up. Rock sites away from kopjes were favoured, as were logs, decumbent trees, hollows in the bases of trees, and the bases of baobabs.

Timed searches were made in hard pan and *C. Fischeri* to compare the deposition of pupae in each. These searches were made in the area where the hard pan and *C. Fischeri* marking experiment, described above, was carried out. All the searches were made by the writer and two skilled natives in favourable sites, every site being searched until no more pupae were found. In the hard-pan bush six live pupae and 200 empty cases were taken in ten hours and thirty-one minutes, or 19.6 pupae and cases per hour's search. For the most part, in thickets near water-courses humus was replaced by hard baked earth, water-sodden in the rains. In such places no pupae were found, but whether the female tsetse did not larviposit, or whether the larvae, being unable to burrow, were eaten by predators, was not determined.

In the *C. Fischeri* bush no searches were made more than three or four hundred yards from hard pan. Six live pupae and 300 empty cases were taken in thirteen hours and six minutes, or 23.4 per hour's search, a figure differing very little from that for the hard pan.

The transition zone between the *C. Fischeri* and the hard pan gave 79.4 depositions per hour's search, including an exceptional haul from the hollow base of an

Acacia usambarensis, where 19 pupae and 288 empty cases were found in two and a half hours. No such concentration was ever found elsewhere.

The combined results give 31 live pupae and 810 empty cases in twenty-seven and three-quarter hours. Compared with ordinary finds of *G. morsitans* pupae this is an exceedingly small figure. In Kikori, Kondo District, a search of equal duration would produce 500 or 600 live *G. morsitans* pupae. No doubt this is because *G. swynnertoni* is mainly a thicket breeder and the pupae are very scattered, whereas the pupae of *G. morsitans* are concentrated under logs and rocks.

4. The Seasonal Variation of *G. swynnertoni* as shown by the Fly-rounds and the Hand-catching Experiment.

No direct correlation was found between the behaviour of the flies and the maximum and minimum temperatures, rainfall or relative humidity, as taken at the Shinyanga open station four miles away. This may be due to the fact that numbers taken on the fly-rounds were small. A good correlation occurred between the composition of the fly-population appearing and the evaporation, as will be seen later on.

(a) *Fly density*.—The number of fly remains fairly constant throughout the "long rains," with a sharp rise towards the end continuing into July or August, when the maximum apparent density is obtained. In the great hand-catching experiment, to be referred to later, the maximum number of flies in both years was reached in June,

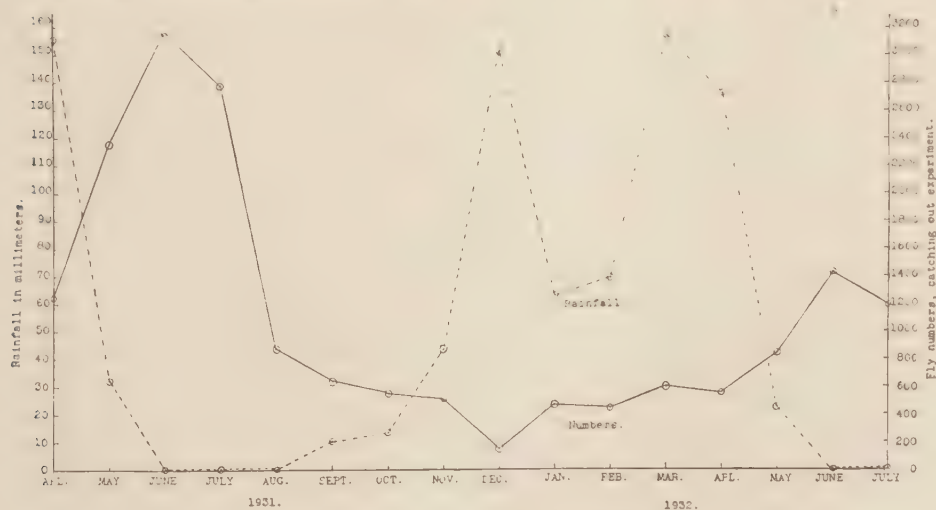


Fig. 3. Total catches per month in catching out experiment and total rainfall each month.

a large drop in numbers occurring in July (fig. 3). This discrepancy can be accounted for by the fact that, while a fly-round does not affect the fly density, systematic and intensive hand-catching does. During the rains breeding kept pace with the subtraction of flies by hand-catching. At the end of the rains, it is supposed activity increased, more flies showing themselves to the catchers, and breeding failed to compensate for catching. Normally during the early part of the "long dry season," when no catching occurs, the fly is able to maintain a high density. For the remainder of the dry season numbers diminish. With the break of the "short rains" there is a sharp drop in numbers, mainly accounted for by decreased activity of the fly. Numbers rise again during the "short dry season," probably as the result of both of the favourable conditions in the short rains and of activity, after which they remain constant up to the return of the dry season.

(b) *Hunger*.—Here again owing to small numbers results were erratic. The period of greatest repletion, however, was at the break of the "short rains" when the most humid conditions obtained.

(c) *Percentage of females*.—This is steady during the rains, after which a rise occurs up to August or September, when there is a slight fall. As with numbers and hunger, there is a large decrease in female percentage during the "short rains."

In the hand-catching experiment the rise and fall of the female percentage month by month follows closely the evaporation rate, which is more or less inversely proportional to the relative humidity (fig. 4). It appears that periods of greatest evaporation and driest conditions intensify hunger and cause the females to appear in relatively large numbers. (Jackson 1933.)

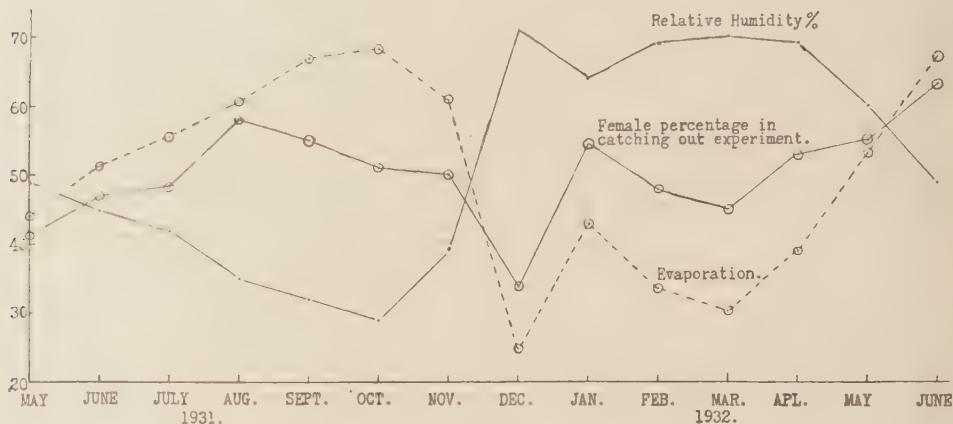


Fig. 4.

(d) *Young fly*.—The numbers were too small for any conclusions to be drawn as to seasonal variations of young fly.

(e) *Hypothetical evacuation of the hard pan during the dry season*.—It has been suggested by Dr. Nash (1933) that the concentrations of *G. swynnertoni* in the hard pan were only seasonal. The concentration was supposed to take place during the rains, when the long grass outside the hard pan becomes inimical to the tsetse. After the grass fires, when this long grass is destroyed and visibility improved, the fly concentrations in the hard pan were supposed to disperse throughout the *C. Fischeri* bush. Frequent reconnaissances and fly-rounds throughout the long dry season have shown that this is not so. At this period the ratio of the number of flies in the hard pan to the number of flies in the *C. Fischeri* appears to be much the same as during the rainy season. If one passes through *C. Fischeri* bush in the long dry season taking but few flies, one is always struck by the increase in density of fly on reaching a hard-pan patch. If the evaporation for three types of vegetation is examined (fig. 1) it may be seen that the conditions during the rains in the hard-pan areas are drier than in the *C. Fischeri*. As the country dries the conditions in the last two types become more equal. In the thickets the evaporation is much less than outside and more equable conditions obtain. In the hard pan more thicket is present than in the *C. Fischeri*, so that when the trees are leafless hard pan may be more favourable than *C. Fischeri* for the fly.

Again, in the *C. Fischeri* the burn is usually cleaner than in the hard pan, where the thicket elements and the poor nature of the grass growth prevent a fierce fire. Consequently large stretches of hard pan often remain unburnt. This, coupled with

the fact that some of the larger streams retain water-holes till the end of the dry season, encourages game to browse there. On this account tsetse on the hard pan will have no difficulty in obtaining food, and the concentrations remain in the hard-pan areas throughout the dry season.

IV. THE SENSES USED BY *G. SWYNNERTONI* IN HUNTING FOR FOOD.

It has been shown that *G. morsitans* hunts by sight rather than by scent (Nash 1930). An experiment originally designed to show whether the scent of animals played any part in attracting flies across clearings suggests that *G. swynnertoni* hunts in the same way.

1. Experiment with Calf Trap.

(a) *Fifty yards crossing No. 1*.—Two of Mr. Swynnerton's calf traps were placed in a clearing two hundred yards apart. The trap consists essentially of a framework supporting hessian, inside which the calf is tethered and completely concealed. Flies entering the trap are caught by a wire gauze cage attached to the top of the framework. For a full description of these traps and their powers of catching see Swynnerton (1933). It may be added that one of these traps with a calf inside repeatedly caught many more flies than did a trap of the same kind but without the calf.

Direction of wind.



Two boxes containing flies were placed at right angles to the line joining A and B, one (C) fifty yards from A and the other (D) fifty yards from B, so that, the wind being from the east, any scent at A or B was carried across to C or D. The boxes were concealed from the targets by intervening coppice. A calf was placed in the trap B, while the control A was set up without a calf. The writer was stationed at B with two fly-boys, and three fly-boys were at trap A. Flies arriving at either trap were not allowed to enter but were immediately caught. The boxed flies were marked with paint beforehand to show their state of hunger and box of confinement. The boxes were of wood except for one side covered with mosquito netting. The flies were released from each box simultaneously by a string attached to the netting of box C and passed to A, and a second string from box D passed to B. The first three days were unsuccessful owing to deaths of flies in the boxes through the hot sun, a difficulty which was overcome by soaking the boxes in water before use.

The following results were obtained :—

<i>Trap with calf (B)</i>					Males	Females	Total
Flies released at D	...	...	...	...	31	10	41
Flies retaken from box D	...	...	...	...	11	4	15
Flies retaken from box C	...	...	...	...	1	0	1
Percentage flies retaken of total released from box D					35.5	40.0	36.6

Whether the flies' behaviour was completely normal on release from confinement cannot be said to be certain.

<i>Control (Trap A)</i>				Males	Females	Total
Flies released at C	...	...	...	37	3	40
Flies retaken from box C	...	...	...	8	1	9
Flies retaken from box D	...	...	...	1	1	2
Percentage flies retaken of total released from box C	...	...	...	21.7	33.3	22.5

This experiment was repeated a second time over the same distance but the number of recaptures was smaller, flies were repleter on the second day and tended to remain round the box instead of leaving in search of food. At the end of the experiment on the second day several marked flies were seen near the boxes, none on the first day when the flies were hungrier.

(b) *Fifty yards crossing No. 2.*

<i>Trap with calf</i>				Males	Females	Total
Flies released at D	...	...	...	27	7	34
Flies retaken from box D	...	...	...	5	1	6
Percentage flies retaken of total released from box D	...	...	...	18.5	16.7	17.6
<i>Control</i>						
Number of flies released at C	...	...	...	29	7	36
Flies retaken from box C	...	...	...	5	0	5
Percentage flies retaken of total released from box C	...	...	...	17.3	0.0	16.1

No flies were taken at either trap from the far boxes.

In both cases the trap with the calf attracted slightly more flies, but this difference is not statistically significant, so that over fifty yards' distance it cannot be said that tsetse were being attracted by scent, and we are left to suppose that the equality in catches at the two traps of uniform appearance argues that flies were attracted by sight.

(c) *Twenty-five yards.*—The conclusion drawn from the two preceding experiments also holds good over twenty-five yards' distance:—

<i>Trap with calf</i>				Males	Females	Total
Flies released at D	...	...	...	26	8	34
Flies retaken from box D	...	...	...	7	4	11
Flies retaken from box C	...	...	...	1	0	1
Percentage flies retaken of total released from box D	...	...	...	26.9	50	32.3
<i>Control</i>						
Number of flies released at C	...	...	...	37	6	43
Flies retaken from box C	...	...	...	7	1	8
Flies retaken from box D	...	...	...	0	0	0
Percentage flies retaken of total released from box C	...	...	...	18.9	16.7	21.7

(d) *Hundred yards.*—When the experiment was repeated over a hundred yards' distance, the recaptures were few, possibly owing to the repleteness of the flies on that day.

	<i>Trap with calf</i>	<i>Control</i>
Flies released	37	36
Flies retaken from near box	1	1
Flies retaken from far box	0	1

Further, flies did not start to arrive any sooner at the calf trap with the smell than at the control (Table IX) ; had scent been attracting them, earlier arrival at the calf trap might be expected.

TABLE IX.

Length of time in minutes between release of flies and arrival of first fly.

Distance	Trap with calf	Control
25 yards	17	22
50 „	15	10
100 „	30	22

It would appear that at over twenty-five yards *G. swynnertoni* does not necessarily hunt by scent.

2. Experiments with Hand-catching Screens.

That *G. swynnertoni* hunts largely by sight is suggested by consideration of flies caught by pairs of natives carrying rectangular cloth screens. An account of these experiments has already been published (Swynnerton 1933). The screen consists primarily of a piece of cloth about 4 by 3 feet. Along one long edge is nailed a bar of wood, overlapping about a foot at each end to enable the two catchers to carry it. The cloth hangs down between them and is kept taut by a second bar of wood nailed to the lower edge.

The catchers took flies impartially from the screen, the ground and the vegetation, and each other. On alternate days they followed a blazed trail mainly through hard pan, stopping at intervals to catch flies attracted ; on intermediate days the same procedure was followed without the screen. The sum of each type of catch is shown in Table X.

TABLE X.

Catch	Males	Females	Total	Female percentage
Screens	1,159	408	1,567	26.0
Control	920	194	1,114	17.4

The percentage of females in the catch with the screens is higher than in the catch without. The screens thus produce much the same effect as bait cattle (Swynnerton 1921, Jackson 1930, Nash 1933). With bait cattle, the rise in female percentage might be attributed to the smell of the cattle ; but as there was no animal scent on the screen, fly must have been attracted by some visual stimulus, such as shape or colour. Though the number of males was only slightly greater with the screen than without, being in the proportion of 1.26 : 1, the number of females was more than doubled, the ratio of the screen catch to the control being 2.10 : 1.

Experimentation on the preference of *G. swynnertoni* for certain coloured cloths gave the following order of preference : dark grey blanket, red brown cloth, medium grey blanket, black cloth, light grey blanket, and hessian. Since various colours have different attractions for *G. swynnertoni*, these flies must have been hunting by sight.

3. A Comparison of Catches with a Grey Blanket Screen of *G. pallidipes*, *G. morsitans* and *G. palpalis*.

It is of interest to compare these catches with similar catches of *G. pallidipes* carried out at the same time, and over the same area, as the catches of *G. swynnertoni*. Experiments with *G. morsitans* also were carried out at Kikori over Dr. Nash's "bait cattle" paths in *Brachystegia microphylla* woodland forming the home of the fly, and screen catches of *G. palpalis* were made on Mugasiro Island in Lake Victoria. The results are summarised in Table XI.

TABLE XI.

Species	Catch with screen				Control			
	Males	Females	Total	Female percent.	Males	Females	Total	Female percent.
<i>G. pallidipes</i> ...	113	63	176	35.8	39	15	54	27.8
<i>G. morsitans</i> ...	2,162	124	2,286	5.4	1,399	31	1,430	2.3
<i>G. palpalis</i> ...	1,212	407	1,619	25.1	1,326	247	1,573	15.7

It will be seen that *G. pallidipes* and *G. morsitans* behave similarly to *G. swynnertoni*. But with *G. palpalis*, instead of the number of males being much greater in the screen than in the control catches, the numbers in both are approximately the same. This is possibly because *G. morsitans* and *G. pallidipes* were collected in bush where visibility was good, and where non-hungry males might be attracted from a distance. Whereas with *G. palpalis* the visibility was exceedingly poor, so that no merely inquisitive males could be attracted from a distance to swell the number of males. More female and hungry male *G. palpalis* were attracted by the oblong screen, which accords with other observations on Mugasiro Island, tending to show that man is not the favourite host of *G. palpalis*.

If we compare the ratio of the catch of males with a screen to the catch of males without a screen, with the ratio of the catch of females with a screen to the catch of females without a screen, we see that the order of magnitude is the same for all four species of fly. It is also interesting to note that with the exception of *G. morsitans* the difference between the ratios are of the same order as those between the female percentages.

TABLE XII.

Species	Catch of males with screen ÷ Catch of males without screen	Catch of females with screen ÷ Catch of females without screen	Female percentage with screen	Female percentage without screen
<i>G. pallidipes</i> ...	2.90	4.20	35.8	27.8
<i>G. morsitans</i> ...	1.55	4.00	5.4	2.3
<i>G. swynnertoni</i> ...	1.26	2.10	26.0	17.4
<i>G. palpalis</i> ...	0.91	1.65	25.1	15.7

This order no doubt represents the inverse preference of these species for man as a host; *G. pallidipes* showing the least.

V. AN EXPERIMENT TO DETERMINE WHETHER AN EIGHT HUNDRED YARDS WIDE CLEARING (FROM WHICH GAME IS EXCLUDED) IS A BARRIER AGAINST *G. SWYNNERTONI*.

1. Determination of Effectiveness of Clearing.

The clearing used ran from north to south between two blocks of bush in Shinyanga. The western edge was bounded by a road, closed to traffic throughout the experiment, and beyond by bush in which fly was fairly dense. The eastern edge was bounded by bush in which fly was scarce. The clearing for three miles was completely fenced in and all the game was driven out of it.

(a) *Complete clearing, except for baobabs.*—In the first part of the experiment, in which large baobabs (*Adansonia digitata*) were left standing at wide intervals, flies along the west side of the middle section (one and a half miles) of the clearing were marked with coloured paints, a different coloured paint being used for every day. Flies following beyond the marking section were killed to prevent as far as possible outflanking of the end fences by flies. Only flies recaptured on the east within four days of marking were counted as successful crossers. After deducting flies that were killed, it was found that for every forty-two flies marked, one fly succeeded in crossing. Evidently this type of clearing is not effective as a barrier against *G. swynnertoni*.

(b) *Clearing in which baobabs were cut down.*—The baobabs were cut down, leaving a completely treeless clearing, and the experiment was repeated. This time, for every forty-four flies marked one succeeded in crossing. One would imagine, therefore, that it made no difference to the effectiveness of a clearing whether baobabs were standing in it or not; on the other hand, subsequent experimentation by Mr. Potts showed that tsetse were really using the baobabs as "stepping stones" to cross the clearing. The discrepancy between the writer's and Mr. Pott's experiments may be partly owing to insufficient numbers of recaptures, and partly to the difference in season. However, it may be stated that an 800 yard clearing in which no trees at all are left standing, and from which game is excluded, is not a complete barrier against *G. swynnertoni*.

2. Point in Clearing where the Flies cross.

Scarce fly

	C	I <i>C. Fischeri</i>	F
B		H	E
Hard pan		CLEARING	Hard pan
		G	
		Road	
A		<i>C. Fischeri.</i>	D

Thick fly
J

The vegetation, before it had been cut down to form the clearing, had not been homogeneous. The rises had been covered with *C. Fischeri* bush, and in the valleys hard pan occurred. It had been suspected from the previous experiments that the flies might be crossing the clearing by following the hard-pan valleys cutting it. Two of these are about three-quarters of a mile apart, approximately midway between the ends of the enclosed clearing, and lying between them is a rise which formerly supported *C. Fischeri* bush.

Flies were marked on the road (west) side of the clearing in the hard pan A and D, differential marking indicating (1) whether marked in A or D, (2) hunger stage, and (3) day of marking.

As there were few flies in this *C. Fischeri* bush between A and D, flies were released there from a wooden box with a muslin cover. As with the other flies, they were marked to show point of origin, hunger, and date of marking. These flies were released at G, half-way between A and D and about twenty yards from the road, by pulling a long string attached to the muslin. Parties of natives caught flies in the vicinity of the points B, H and E, which were just inside the clearing, and near C, I and F which were outside the clearing.

If flies were crossing the clearing along the hard-pan valleys it would be expected that the majority of recaptures from A would be taken at B and C, and the majority of recaptures from D at E and F, whilst of the flies released at G recaptures would occur at B, C, E and F, no recaptures being taken at H or I. On passing from A to D and from D to A frequent halts were made to kill and record any marked following flies. After the flies had been released at G this point was not passed until the next day, so that the catching party should not attract the flies to themselves. At the end of each day on passing out of the area, as in the first two experiments, marked flies following were killed and noted.

After subtracting flies that were killed there remained the following potential crossers :—

Area of marking	Males	Females	Total
D	911	418	1,329
A	527	319	846
G	486	116	602

Tables XIII, XIV and XV denote the distribution of the recaptured flies.

TABLE XIII.
Flies marked in D.

Place of recapture	Males	Females	Total	Total as a percentage of the total flies marked in D
E	9	7	16	1·20
H	1	1	2	0·15
F	13	13	26	1·96
C	1	0	1	0·08
I	1	0	1	0·08

TABLE XIV.
Flies marked in A.

Place of recapture	Males	Females	Total	Total as a percentage of the total flies marked in A
B	1	0	1	0.12
E	5	4	9	1.06
H	1	0	1	0.12
C	2	5	7	1.06
F	5	2	7	1.06
I	1	0	1	0.12

TABLE XV.
Flies released at G.

Place of recapture	Males	Females	Total	Total as a percentage of the total flies released at G
H	1	1	2	0.32
E	8	2	10	1.66
I	2	1	3	0.49
C	1	1	2	0.32
F	5	2	7	1.16

It can be seen that flies were crossing the clearing not merely along the hard-pan valleys but also across the clearing at positions which had formerly supported *C. Fischeri* bush, as two flies released at G were retaken crossing the clearing at H.

Referring to Table XV it might be thought that more of these flies were crossing by the hard-pan valleys than over the rises, as a much higher percentage of flies was taken at E and F than at the corresponding positions H and I. However, on looking at the flies taken at B and C from G we find a smaller percentage of flies was taken at these positions than at the corresponding places H and I. Thus it cannot be said that more flies were crossing by the hard-pan valleys.

Movement of flies from G in the direction D, E, F, seems to have taken place before the flies crossed the clearing, as of the flies released at G 29 were retaken while marking at D, and only 9 while marking at A. Similarly of the flies marked at A 37 were retaken while marking at D, but only 10 of the flies originally marked at D were retaken whilst marking at A. This movement was not due to traffic along the road, which was closed, and no tracks were found along it. Whilst passing from A to D or D to A for the first hundred yards marked following flies were driven away; after a second hundred yards as many as possible of the persistent followers were caught, killed and recorded, and frequent subsequent halts were made to kill and record any

that remained. The passage from A to D was done at approximately the same time each day, and the passage from D to A approximately an hour and a half later than from A to D. It was, therefore, suggested that flies were more persistent in following at the time when the party passed from A to D than at the time when the party returned from D to A. This is possible but improbable, as few marked flies were killed after the stop at the end of the first hundred yards in which flies were merely driven away. Certainly far more than 37 flies must have passed from A to D, and far more than 10 from D to A, as the numbers recaptured would represent only a fraction of the actual number of flies that were involved. In view of the very thorough searches always made for marked flies following, it is improbable that large numbers were carried unnoticed by the marking party. But the movement is sufficient to invalidate comparison of the relative number of flies crossing at various points of the clearing.

3. Proof of the Validity of the Crossing Experiments.

It was thought that possibly the flies might be moving down the road to each end of the enclosed clearing, and then being carried across by game outside the enclosure. Accordingly while the last part of the experiment was in progress, boys were catching outside the enclosure at each end on a level with B, H and E. In these two catching sites at the ends of the clearings only four marked flies were taken, whilst at B, H and E 41 marked flies were taken. Had marked flies been out-flanking the fenced ends of the clearing, more would have been taken there than at B, H and E; since the reverse was true, it follows that flies were not outflanking the fences, and therefore that they were crossing the fenced portion without assistance from game animals.

4. Cause of Flies crossing the Clearing.

That the cause of the flies crossing the clearing was a hunger stimulus may be seen from the fact that the hungry flies crossed the clearing sooner than did the repleter ones. In part (i) of the experiment described in paragraph (a) the flies were

TABLE XVI.

Numbers of Flies crossing the Clearing on each Day after Marking.

Hunger stage ...	Interval in days				
	0	1	2	3	4
I	0	0	0	1	0
II	0	1	4	1	1
III	0	9	2	0	0
IV	5	32	7	3	1
Young males	2	1	0	0	0
Old females	6	30	2	1	1
Young females	0	3	0	0	1

not marked to show hunger, and this point could not be demonstrated. However, data are available from part (ii). Two stage IV flies were caught having crossed on the day of marking, 10 stage IV flies on the day after marking, and the other fly that crossed was a stage II fly, three days after marking. These data are supported by data from paragraph (b).

The only stage I fly that crossed did so three days after marking. The majority of stage II flies crossed two days after marking, and the stage III flies one day after. The hungry flies (male and females of stage IV and young flies) crossed mainly on the day after marking, but there was a tendency to cross on the same day. Further the female percentage of the flies that crossed the clearing was higher than that of the total number of flies marked.

TABLE XVII.

Area of marking	Total number of flies marked				Number of flies crossing			
	Males	Females	Total	Female %	Males	Females	Total	Female %
D	911	418	1,329	31.5	28	24	52	46.2
A	527	319	846	36.5	19	17	36	47.2
G	486	116	602	19.3	18	8	26	30.6
Total	1,924	853	2,777	30.7	65	49	114	43.0

Females are usually only active when hungry. Thus, other things being equal, the higher the female percentage, the more hungry are the flies in general, and Table XVII supports the suggestion that hunger stimulates the crossing of the clearing by fly.

5. Tenacity of following Flies in relation to Hunger.

In the third part of the clearing crossing experiment it was stated that when the party left one marking area, marked flies were driven away, and afterwards as many as possible were caught and killed. In Table XVIII the flies noted as "following" include only those killed on the day of marking.

TABLE XVIII.

	Males	Females	Total	Young Males	Young Females	Stage			
						IV	III	II	I
Flies marked ...	1,827	830	2,657	145	147	974	442	200	66
Flies following ...	130	22	152	10	6	90	27	2	1
Percentage following	7.0	2.1	5.7	6.9	4.1	9.2	6.1	1.0	1.5

It is apparent that males are more persistent followers than females. As would be expected (Jackson, 1933), hungry flies follow more persistently than less hungry ones. The single stage I fly that followed was a partially fed individual.

VI. AN ATTEMPT AT EXTERMINATION OF *G. SWYNNERTONI* BY HAND-CATCHING.

1. Description of Experiment.

The attempt was made at Shinyanga in a block of country (5A) where fly was fairly scarce, from March 1931 to July 1932. The block of country is bordered on the east by fly free cultivation steppe. To the north and west the block was separated from thick fly bush by a clearing 800 yards wide. To the south was bush containing sparse fly also cut off from the experimental block by a clearing 800 yards in width. It has

been seen above that an 800 yard clearing is not at all "fly-tight." To reduce re-infestation from outside of the catching-out area, flies were caught also in concentrations bordering the clearing.

The area of the block was about fifteen square miles. The fly was commonest in hard-pan strips sandwiched between *Commiphora Fischeri* areas in which flies were very scarce. There were also an area of thicket, a piece of nearly pure *Dalbergia melanoxylon* bush, and an area of *Acacia* parkland, all of which were practically fly-free.

The catching was done by about sixty natives armed with gauze catching nets. Ten of these natives were trained fly-boys, while the remainder were native children who soon became very proficient. They were divided up into parties varying from two to ten in number, each party being assigned to one hard-pan area, larger parties having larger areas. The parties were divided into pairs, each pair carrying a dark grey, rectangular catching screen. Every party was supervised by a trained fly-boy, and visits were paid by the writer up to November 1931, when Mr. H. Harrison, Reclamation Assistant, took over the work for six months. At first no catches were made in the *Commiphora Fischeri* bush; later daily catches were instituted in two areas of this type.

2. Results.

(a) General.

The total number of *G. swynnertoni* taken in the isolated block was 24,306 of which 50.9 per cent. were females. In addition 1,267 *G. pallidipes* were caught, of which 49.7 per cent. were females. Outside the clearings 55,045 *G. swynnertoni* with a female percentage of 40.6 and 1,396 *G. pallidipes* having a female percentage of 40.5 were caught. The striking feature of these catches is the high female percentage, which rose as the work proceeded, as shown in Table XIX, where particulars for nine of the hard-pan patches in the block are given. The block is not taken as a whole because other areas besides these nine were introduced during the progress of the catching.

TABLE XIX.

Total monthly catches from nine hard-pan areas.

Month	Males	Females	Total	Female percentage
1931				
April	1,087	363	1,450	25.2
May	1,396	986	2,382	41.4
June	1,683	1,499	3,182	47.1
July	917	861	1,778	48.4
August	368	505	873	57.9
September	291	354	645	54.9
October	272	279	551	50.9
November	258	258	516	50.0
December	100	51	151	33.8
1932				
January	212	255	467	54.6
February	238	220	458	48.0
March	332	271	603	44.9
April	260	293	553	53.0
May	372	469	841	55.8
June	528	901	1,429	63.1
July	460	735	1,195	61.5

(b) Effect on female percentage.

If we compare month by month the curve of the female percentage in the nine hard-pan catches with that of the female percentage on a control fly-ground passing through hard pan in the control block 4B (fig. 5), it is evident that the female percentage in the "catching out" area is abnormally high after the first two months of catching. During the initial rise in female percentage at the start, the number of females have exceeded more and more the number of the males, thereafter remaining in considerable excess throughout the rest of the experiment. Though the sexes emerge in equal proportions from the pupae, the males generally predominate in catches, the females showing themselves only when hungry. If there are few catches during the month, as on the control fly-round, the removal of a few more males than females from a large population will not upset the sex ratio. However, if more males than females are removed continuously, in time the females will in fact exceed the males, although by no means the whole of this excess will appear in catches made. Probably for this reason also, the experiment failed to effect a radical reduction in numbers. It is possible that the males suffice to serve all the females, whether the sex proportions are equal or whether there are twice as many females as males, since every female must periodically show herself to feed. Though the number of males was reduced by about half from July 1931 to July 1932, the number of females was reduced by about one and a-half tenths only. The rate of breeding, therefore, does not seem to have been much affected.

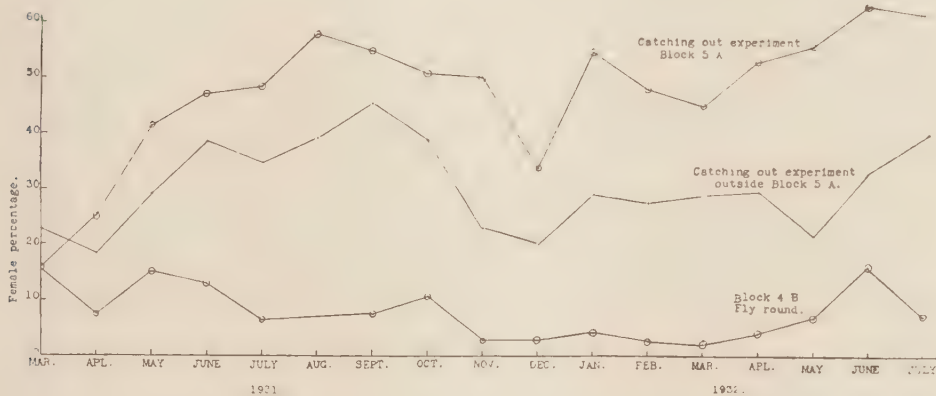


Fig. 5.

The curve of the female percentage of the catch rose during the first five months of catching, the peak being reached by August 1931, on the 10th of which month the organised grass fires took place. These fires might also help to raise the female percentage, because more females than males might be expected to retire to thickets or other shelter, gaining more protection from the fire.

After August the female percentage gently fell off, possibly owing to the deaths of females that had survived the fire. When the rains broke in December and conditions became less severe there was a large drop in female percentage, coincident with a rise in numbers and a fall in hunger of the fly. In January, the short dry season, the female percentage rose again; from then until the end of the rains it was lower, until the rise at the advent of the long dry season.

The curve of the female percentage of the continuous catches outside the catching-out block behaves as would be expected. It runs a middle course between the female percentages of the catching-out block and those of the periodic control catches from

the fly-round. It rose following the catching-off of males ; but could not attain the height of that of the catching-out block, owing to continual influx of fly from the surrounding bush ; hence the general form of this curve follows that of the catch.

(c) *Effect on male flies.*

During the experiment 63 males were marked and released. Of these flies 43, or 68·3 per cent., were recaptured. Though the numbers here are very small and thus not conclusive, they indicate that a very large proportion of the *male* population was being caught. The recaptures of these flies extended over a period of a month, showing their ability to elude the catchers while obtaining food. Had females been similarly marked, no doubt the percentage of recaptures would have been smaller.

(d) *Effect on G. pallidipes.*

The catches of *G. pallidipes* in these nine hard-pan patches did not agree very closely with those of *G. swynnertoni* ; this may be largely due to the smallness of the catch of *G. pallidipes*, which were not so reduced in numbers as were *G. swynnertoni*. The catches of *G. pallidipes* for June and July 1931 were 111 and 83 respectively, compared with 83 and 72 in the same two months of 1932. The maximum catch, 112 flies, was in September 1931. The fluctuations in female percentage were erratic.

(e) *Comparison with G. palpalis.*

In a similar experiment on *G. palpalis* by Koch (Koch 1914) on Mugasiro Island in Lake Victoria from January 1913 to January 1914 a similar rise in female percentage was observed. From January 1913 to May of that year the female percentage rose from 25·7 to 38·7 ; this may, however, have been due largely to season. The female percentage then fluctuated considerably, finishing at 33·1 in January 1914, 7·4 higher than in the preceding January. This difference might have been due to physical factors, but a rise is shown in the figures which follow. Koch took in all 74,382 flies of which 32·9 per cent. were females. The writer studied *G. palpalis* by the fly-round method on Mugasiro from March to July 1933. The flies were marked with paint and released in order to avoid disturbance of the population and sex ratio. In all 11,959 flies were marked of which 19 per cent. were females. Koch's female percentage was 14 above that of the fly-round. This may well represent the amount by which Koch raised the female percentage, as it is not likely that the habits of *G. palpalis* would change sufficiently in twenty years to account for the difference. No doubt, in view of what has been said above, had Koch used catching screens the female percentage of his catch would have approximated to 50 ; Koch on plotting the total catch per month against the total rain per month found that generally speaking the two curves ran parallel. For *G. swynnertoni* the relation was found to be inverse (fig. 3), and the maximum catch each year was made during the first month of complete drought following the rains.

(f) *Conclusions.*

The organised hand-catching reduced the fly population. The reduction would have been greater had the bounding clearings been wider. The diminution in numbers was largely due to the catching off of males, the total number of females being less reduced. The main obstacle to success appears to be that the rate of breeding is little affected owing to the ability of the females to conceal themselves and to feed without showing themselves to the catchers.

VII. SUMMARY.

1. *G. swynnertoni* is a source of danger to man and to cattle. Until reclamation was started it was rapidly advancing in the Shinyanga District and was driving the native population in front of it.

2. Round Shinyanga this species occurs in gently undulating country supporting four main types of vegetation, namely :—(a) a *Commiphora Fischeri* community found on the well-drained rises with a good grass growth ; (b) a *Lannea humilis*-*Commiphora Schimperi* community on low-lying hard-pan areas in which the grass is poor and patchy ; (c) communities in which the grass growth is good and the main trees are *Acacia* spp. ; (d) a plains community, partly treeless, partly covered with shadeless woods of the small gall acacias, which are swampy during the rains and very dry at other periods of the year ; during the dry season the trees are completely leafless, and very dry and severe conditions prevail.

3. Game is in moderate numbers throughout the year, so that there is no lack of food in any type of vegetation.

4. The majority of flies living in the hard-pan areas obtain and digest their food there. Flies behave similarly in the *C. Fischeri* association, but some of them whilst searching for food may encounter a hard-pan area, where they will continue their search for food. When they get food they may or may not return to the *C. Fischeri* association to digest it. If a fly strikes a road or open plain it will patrol this until it finds food, when it will return to more sheltered vegetation to digest it.

5. *G. swynnertoni* is mainly a thicket-breeder, though pupae are also found under decumbent logs, overhanging rocks and in hollows at the bases of trees. Where the *C. Fischeri* was much broken up by valleys of hard pan, breeding was found to be taking place to the same extent in the thickets of both of these types.

6. *G. swynnertoni* is commonest in hard pan, much less common in *C. Fischeri*, scarce in the *Acacia* bush types worked in Shinyanga, and least common in the open plains.

7. When flies are numerous, each of the first three types enumerated in (2) is able to support a fly-community. When the flies are scarce, the *C. Fischeri* and the *Acacia* communities lose their flies to the hard pan and hence are little infested. The hard pan is to a far greater degree self-contained as regards the requirements of the fly.

8. *G. swynnertoni* is commonest during the first month or two of the dry season. As the dry season progresses it decreases in numbers and reaches its minimum during the short rains. There is a rise in the short dry season following the improvement of conditions brought about by the early rains ; after this numbers remain fairly constant until the end of the long rains. Hunger and female percentage are least in the beginning of the break of the short rains.

9. There is no indication that the concentrations of fly in the hard-pan areas disperse at the end of the rains.

10. Like *Glossina morsitans*, *G. swynnertoni* appears to find food by sight rather than by scent. The part that scent plays in the matter has hardly been finally elucidated.

11. *G. swynnertoni* is capable of crossing an 800 yards clearing without the assistance of game, irrespective of whether the clearing passes over alluvial or eluvial soil. It is the hungry flies mainly that cross. They are presumably searching for food.

12. The hungrier a fly is the more persistent it is in following man. Males are more persistent followers than females.

13. An experimental attempt was made to exterminate *G. swynnertoni* by hand-catching off screens in a block of 15 square miles during sixteen months. Reduction in numbers occurred, but flies continued to exist in the block because the isolating clearings were too narrow. Further, female flies do not appear sufficiently readily to catchers, so that breeding is able to continue.

14. A very large rise in female percentage occurred. A similar but lower rise marked an experiment in the catching-out of *G. palpalis* by hand on Mugasiro Island, near Musoma, by Robert Koch in 1913. In this the catching was off man only.

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THE LILY THRIPS (*LIOTHRIPS VANECKEI*, PRIESNER).

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(PLATE XVIII.)

Introduction.

In 1920 Priesner² described, from material collected in Holland in 1915, a new species of thrips which he named *Liothrips vaneckei*. Since 1920 this thrips has from time to time been recorded from various countries and appears to be very widely distributed. Nevertheless, information as to its habits and economic status has remained singularly meagre, the only account of the biology being a short paper in 1932 by the American workers Schopp & Doucette.³ The first official record of occurrence in this country is as recent as November 1933, when the Ministry of Agriculture¹ noted the presence of the thrips in Buckinghamshire in imported bulbs of *Lilium croceum*. Towards the end of 1933 and early in 1934 commercial growers of lilies on several occasions directed the writer's attention to the presence of the insect in England and requested advice as to how best it might be combated. It has proved impossible to undertake as comprehensive a study of the problem as might be desired, but such information as is now available is recorded here.

Distribution and Host Plants.

Priesner (1920) gave the known distribution as Holland, Austria, Italy, Japan, and North America. Schopp & Doucette (1932) reported that the United States Quarantine Board had intercepted *L. vaneckei* in lilies from Holland, Italy, Russia, France, and Canada, and in one instance on an orchid from Ceylon. These writers further suggested that it was known also in England and Belgium and were of the opinion that it might be indigenous to Oregon, U.S.A., where it occurs in abundance upon a native lily, *L. washingtonianum*. Also in 1932 van Poeteren⁴ recorded the thrips in bulbs of *L. martagon* imported into Holland from Italy. The first authentic record in England, referred to above, was in November 1933, but information furnished by commercial growers rather suggests that it may have been sporadically present in the country for approximately the past ten years. As opposed to this suggestion the detailed records of occurrence known to the writer still relate to imported bulbs. They are as follows :—

In 1933, in *Lilium croceum* recently imported, country of origin unknown ; *L. croceum* imported in 1932 and grown here one year ; and *L. carniolicum* newly imported from U.S.A. In 1934, in *L. michiganense* newly imported from U.S.A. ; *L. pyrenaicum* newly imported from Holland ; in the same species grown two years in England ; and finally in *L. pomponium* grown one year after importing from Holland. The above records relate to five species of lily and Schopp & Doucette list a further nine species on which the thrips has been found in America. The inference therefore is that very many species of lily are prone to attack. A point of interest attaches to the fact that there is no record of attack upon the widely grown *L. regale*, and it is possible that this and other species in which red or purple coloration predominates in the bulb-scales are to some extent resistant. At the same time the writer experienced no great difficulty in establishing the thrips on *L. regale* and rearing it through several generations on this host. Further, no record appears to exist of the occurrence on *L. longiflorum* and the allied species of lily so largely used for forcing in this country. Here again the writer with ease induced flourishing colonies of the thrips to build up

upon commercial samples of bulbs taken from cold store. It would therefore appear advisable that careful watch be kept for the pest both here and in the principal countries from which these bulbs are exported.

Description.

Adult (Plate XVIII, *a*).—Shining glossy black; 3 median segments of antennae, lower portions of tibiae, tarsi, pale yellow; tarsal claws dusky. Antennae 8-jointed, wings well developed, forewings with 3 prominent spines on anterior margin. Sexes similar in appearance but males smaller, size variable, average length, male 2.55 mm., female 2.65 mm.

Ovum.—Cylindrical, ends rounded, light amber more or less opaque, chorion finely reticulated, length 0.5 mm.

First instar larva.—Yellowish then pink; head, basal and terminal segments of antennae, thoracic plates, femora and tip of abdomen, sooty; average length at maturity 1.6 mm.

Second instar (Plate XVIII, *b*).—Colour deeper salmon pink; head, basal and terminal segments of antennae, thoracic plates, femora and tip of abdomen, shining black; average length at maturity 2.6 mm.

Pre-pupa (Plate XVIII, *c*).—Lighter salmon pink, eyes red, antennae colourless and translucent, greatly reduced and carried in front of head, wing-pads barely visible; average length 2.6 mm.

Pupa (Plate XVIII, *d*).—Colour as formerly, darkening as maturity approaches; antennae prominent and flexed back towards anterior margin of thorax. Wing-pads colourless, translucent, long and prominent. Average length 2.6 mm.

Injury caused.

The degree of injury exhibited by an infested bulb is dependent upon both the size of the thrips population present and the length of time over which the infestation has persisted. A bulb lightly or only recently infested may, when lifted, superficially appear to be entirely normal. If the scales of such a bulb be parted carefully congregations of thrips in all stages of development will be disclosed, particularly in the basal regions of the outer scales. Typical brownish or rust-coloured and slightly sunken lesions, induced by the feeding punctures, are present on the scale surfaces, and in the interstices of these lesions it is usual to find quantities of eggs. The boundaries of these injured areas are generally more or less clearly delineated, for the thrips are essentially gregarious, both adults and larvae feeding in close company.

More heavily attacked bulbs show a definite loss of turgidity. The scales become flabby, and the outmost ones are thin and paper-like and if handled readily break away from the bulb. Nevertheless the direct result of the thrips feeding is not, unless the population be large, so very serious, and it seems that in the absence of other troubles a bulb can without fatal results sustain a considerable population for a long time. Unfortunately in practice it is typical to find that thrips-infested bulbs become invaded by other pests, notably by the millepede, *Blanjulus pulchellus*, by bulb mite, *Rhizoglyphus echinopus*, by the larvae of the small bulb fly, *Eumerus tuberculatus*, and eventually by various fungi and bacteria. These latter clearly obtain easy access by way of the already injured scale tissues; subsequently the base plate becomes involved, and it is common to lift thrips-infested bulbs which have become reduced merely to a handful of scales, each entirely or partly detached from its neighbours.

Aerial portions of the plants are not attacked, and in view of the number of ills to which lilies are prone it is difficult or impossible to diagnose the presence of thrips from above-ground symptoms. Heavily infested bulbs may fail entirely to grow, and every gradation from a complete failure to a lightly infested and superficially



Liothrips vaneckei, Priesner.: a, adult (x 36); b, larva (x about 41); c, prepupa (x about 37); d, pupa (x about 37).

healthy plant is to be met with in the field. Again it is not unusual to find a well-grown bulb harbouring quantities of thrips even after having been two or three years in the ground. As observation suggests that spread from bulb to bulb is principally effected in the storeroom, it must be inferred that at least in some such cases the thrips have been present since the bulbs were planted. It therefore appears, as suggested above, that in the absence of other injurious organisms a lily bulb will show a very pronounced tolerance to thrips infestation.

Life-History and Habits.

The insect is essentially gregarious, and it is usual for all stages in the development to be passed between the bulb-scales. During the greater part of the year colonies numbering often several hundred individuals in various stages of growth may be found if an infested bulb be broken up. A typical colony of say 50 individuals clustered upon the inner surface of a bulb scale and comprised of jet black adults, black and orange larvae, salmon pink pupae and prepupae, interspersed with cast skins and eggs, presents a striking spectacle. On being disturbed adults, larvae, and pupae alike raise their posterior extremities in a manner frequent in thrips, and highly reminiscent of the behaviour of certain Staphylinid beetles, and move fairly rapidly in search of a darkened retreat. A pungent and distinctive but not unpleasant odour is emitted by the thrips, and it is sometimes possible on this account alone to diagnose their presence within an apparently sound bulb. The purpose of this scent can only be a matter of conjecture, but it is perhaps significant that it is rare to find the thrips carrying hypopi of the bulb mite, even in bulbs in which the latter are so numerous as completely to cripple such other denizens as millepedes. From November to March it is unusual, except within bulbs in store, to find eggs or pupae, and at least in this country the species normally overwinters in the adult and second larval stages.

The number of generations annually is at least four and may probably, under favourable circumstances, amount to as many as seven. Schopp & Doucette³ suggest that reproduction may sometimes be parthenogenetic. The writer has found no evidence to support this hypothesis, males are abundant at all seasons and may be observed to mate freely wherever a colony is kept under observation at a reasonably high temperature.

Mode of Spread.

Normally the whole life-cycle is passed between the bulb-scales, and as long as the bulb contains sufficient nutriment a succession of generations continues. When an attacked bulb becomes extensively decayed both adult and pupal stages tend to wander into the adjacent soil but appear loath to desert the immediate vicinity of the bulb. The adults are well equipped with wings, but the writer has never observed them in flight, and in fact repeated attempts to induce them to take wing have proved quite abortive. Normally the thrips do not frequent the aerial portions of the plants; immature stages never do so and it proved impossible to rear larvae on leaf or stem tissues. Quantities of infested bulbs have been grown under observation, but only when these have entirely decayed in late summer as a result of combined thrips and millepede attack have adults appeared above ground. In such circumstances adults are to be found sparingly on the dried stems and have subsequently been recovered from previously unaffected bulbs near by. There is every indication that this spread in the field is a slow and haphazard process, an observation amply borne out by such examinations as have been possible in commercial plantations.

In store the position is very similar, so long as the temperature remains low, and when this is the case only from very much rotted bulbs is migration likely. However, immediately stored bulbs are exposed to temperatures of about 55°F. and over the thrips become very active, adults in considerable numbers wander openly over the

bulbs and even larvae and pupae become restless and vacate their places of concealment. In this way large quantities of bulbs may become infested in a very short space of time, and in the writer's opinion it is whilst bulbs are in store or in transit that the spread of infestation most usually takes place.

The Life-Cycle.

As pointed out previously, this study is not so complete as might be desired. For example, data as to the duration of the various stages at summer soil temperatures are not available, and the information given here relates only to individuals kept at temperatures fluctuating between 58°F. and 65°F. It is probable that under normal conditions all stages would be somewhat more prolonged, in fact working at "room temperature" Schopp & Doucette found that the average duration from egg to adult was 60 days, as compared with the 44 days under the conditions mentioned above. At the same time some doubt is cast upon the accuracy of the American observations. It is stated that "There seems to be no prepupal stage in this species, for no evidence has been noted of any intermediate stage between the larva and pupa." There is, of course, a prepupal instar, it would be astounding if there were not; and although the stage persists only for some 48 hours, it is so dissimilar in appearance from either larva or pupa that failure to observe it cannot but suggest that the observations as to the other stages may lack accuracy.

The writer has reared numerous colonies of this thrips within the temperature range cited previously, several different species of lilies being utilised. Under these conditions the average duration of the life-cycle is as follows:—Egg 14 days; larva, first instar, 9 days; second instar, 11 days; prepupa, 2 days; pupa, 8 days; total, 44 days. The average number of eggs laid by individual females was 51, the average life of adult females extended to 56 days, and of males to 35 days. Females each mated several times, the first pairing usually taking place on the 5th day after emergence, and egg-laying commenced on about the 14th day.

All stages became torpid at temperatures below 40°F., and under such conditions the life of adults and 2nd instar larvae was very materially prolonged. When stages other than these were subjected to low temperatures for any great length of time the mortality was high. Under outdoor conditions in this country the number of generations annually was not accurately determined, but appeared to be not less than four.

Methods of Control.

It is abundantly clear that any attempt to eradicate this pest is most likely to succeed if made at a time when the bulbs are out of the ground. The effect of immersion of infested bulbs in insecticidal fluids at normal atmospheric pressure and under conditions of high pressure and of partial vacuum was first examined. No satisfactory control was obtained by these means, it proving impossible even under reduced pressure to penetrate sufficiently far into the bulbs to effect a reasonable destruction of thrips. An additional objection lies in the fact that if large quantities of bulbs have to be handled their subsequent drying presents no little difficulty. In view of this result fumigation was resorted to.

Fumigation.

On a small scale hydrocyanic acid gas, carbon bisulphide, tetrachlorethane, and paradichlorobenzene were employed, the last named being finally selected as most suited to the purpose.

During the small scale preliminary attempts it was ascertained that provided the fumigation was sufficiently prolonged a complete kill was assured, not only of the thrips but also of mites, millepedes, and the numerous other common denizens of

lily bulbs. At the same time it was clear that paradichlorbenzene, provided that certain conditions were fulfilled, had no injurious effects upon the dormant bulbs.

As a result of the success attending the earlier experiments it was decided to carry out more extensive fumigations. The work was in fact commenced upon a scale likely to prove of commercial use and reasonably capacious fumigating boxes were employed. Box fumigation is widely used for a variety of purposes in U.S.A. and in certain European countries, but in England, except in a few bulb nurseries, the process is practically unknown. This being so, a brief description of the type of container best suited to the purpose may be of value.

The available capacity of the container must depend upon the quantities of bulbs likely to be handled at any one time, and it is in practice convenient to have several smaller boxes in preference to a single large one. Each box should be of rectangular shape and in a medium-sized nursery or bulb store may have a capacity of approximately 18 cu. ft. to 27 cu. ft. It should be well constructed, preferably of stout well-seasoned timber, and must be reasonably gas-tight. One side should be easily removable and capable of being bolted tightly in position by means of wing-nuts. Within should be accommodation for a series of shallow wire-bottomed trays, placed vertically one above the other, with an air space of some inches between each. Every fourth tray should have, in addition to the wire, the bottom backed with a layer of hessian or other coarse fabric. Bulbs are loaded in single layers upon the wired trays and crystals of the fumigant spread upon those backed with fabric.

The boxes should for preference be housed in premises in which it is possible to maintain an equable temperature of from 55°F. to 65°F. Too low a temperature necessitates undue prolongation of the fumigation, too high a temperature is detrimental to the bulbs, whilst violent fluctuations promote "sweating" and subsequent injury to the bulbs.

The above outline should serve to assist in an understanding of the method of procedure, while the somewhat more detailed account to follow should provide sufficient information to enable fumigations to be undertaken without mishap.

The Fumigant.

The refined crystalline form of paradichlorbenzene should be used. This chemical has the advantage over many common fumigants in that it is of low toxicity to man. The smell is not unpleasant, and causes little or no discomfort to persons carrying out the fumigations, provided that it is not inhaled too freely for lengthy periods within a confined space. In the latter circumstances, it has been known to give rise to severe headache.

The initial charge should be at the rate of 3 oz. of fumigant to every cubic foot of space within the fumigation chamber, the crystals being scattered evenly over the bottom of every fourth tray. In the remaining trays the bulbs should be placed and except in the case of very small ones should be arranged in single layers, leaving always an air-space between the bulbs and the tray immediately above. Paradichlorbenzene is not highly volatile and at the temperature range advised, viz., 55°F. to 65°F. wastage is not excessive. It has been found in practice that the addition after each consecutive fumigation of from one-sixth to one-quarter the initial dose serves to keep the concentration at the desired level. This holds good only if the boxes are well constructed and are kept tightly closed except when bulbs are actually being loaded or removed.

Duration of Fumigation.

It is essential, if the fumigation is to be completely effective, that it be sufficiently prolonged. At a temperature of 58°F. large and medium-sized bulbs require fumigation for not less than 96 hours, and small bulbs from 60 to 80 hours. It is likely that the requisite duration could be shortened very materially if the temperature were

raised considerably. No such modification can be advised until further work has been carried out, for the effects of higher temperatures upon the bulbs themselves have yet to be ascertained.

Precautions to observe.

Injury to fleshy roots and bulb-scales of even quite small and delicate bulbs as a result of fumigation has only exceptionally been observed. On the other hand it is inadvisable, until first-hand experience of the process has been obtained, to attempt the fumigation of bulbs showing any top-growth whatever. If this top-growth has remained white it is likely to emerge quite uninjured, but active green top-growth has, in the writer's experience, sometimes been very severely scorched, with resultant injury and check to the bulbs themselves.

It has been found best to rest bulbs for a few days in store between the time of lifting from the soil and placing in the fumigation chamber. This permits excessive moisture to evaporate and also obviates the necessity for a sudden and violent change of temperature within the bulbs. Under no circumstances should wet bulbs be fumigated, but they may be damp enough to avoid the drying out of the main fleshy roots. On removal after fumigation they may be, as circumstances dictate, either returned to store, or immediately replanted.

Conclusion.

These investigations have disclosed the not infrequent occurrence of lily thrips in this country. It has further become clear that vast quantities of lily bulbs are annually lost as a result of attack by pests. The process of fumigation outlined above has already been adopted by certain leading commercial growers of lilies, and may with equal satisfaction be adopted for use on bulbs of narcissus, tulip, and gladiolus. It can be confidently asserted that the installation and regular employment of suitable fumigation apparatus will amply repay the outlay and additional handling involved, and that such apparatus should form part of the equipment of all the leading bulb-growers in this country.

Summary.

1. Attention is drawn to the presence of *Liothrips vaneeckei* upon lilies in this country and reference is made to its known distribution and host plants.
2. The various stages of the thrips are described and figured.
3. The life-history and habits, together with the injury caused, are discussed.
4. Control measures are considered. A method of fumigation with paradichlorobenzene is described, and the necessary apparatus to employ and technique to observe when fumigating upon a commercial scale are outlined.

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THE GENUS *TACHARDINA* (LACCIFERIDAE, COCCIDAE) IN SOUTHERN AFRICA.

By W. J. HALL, D.Sc.

Mazoe, Southern Rhodesia.

Such knowledge as we have of the family LACCIFERIDAE is very largely embodied in an excellent monograph published in 1923 and 1925 by J. C. Chamberlin (Bull. Ent. Res. **14**, pp. 147-212 and **16**, pp. 31-41). The comparatively speaking limited geographical distribution of the various generic groups is well brought out in this monograph. Thus, for instance, the genera *Tachardiella* and *Austrotachardiella* are apparently confined to North and South America, *Metatachardia* to Ceylon, *Austrotachardia* to Australia, *Tachardia* to India and the Far East. Chamberlin further states (p. 149) "in general it may be said that the species of this group are tropical or sub-tropical, apparently reaching their greatest abundance in regions of limited rainfall." How far this comparatively limited and well-defined zonal distribution of the various genera will hold good as further material is collected will prove of the greatest interest.

Very few species have been recorded or described from Africa up to the present time and, so far as is known, these all belong to the subfamily TACHARDININAE. This subfamily has been divided by Chamberlin into two genera—*Afrotachardina* and *Tachardina*.

Only two species of the genus *Afrotachardina* are known—both from Uganda. The genus *Tachardina* is divided into two groups—the group of which *T. albida*, Ckll., is taken to be typical and that of which *T. decorella*, Mask., is representative. It will be shown below that all the species known from Southern Rhodesia and the Union of South Africa fall into the *albida* group. There is only one known representative of this group that has been recorded from outside Africa—*T. aurantiaca*, Green, from Java and the Malay Peninsula.

I am greatly indebted to Dr. T. J. Naudé, Chief Government Entomologist in the Union of South Africa, for the loan of material from the collections in his Department and for his permission to incorporate my remarks upon it in this paper. It is also a pleasure to record my very grateful thanks to Mr. H. K. Munro, Collection Entomologist in the Department of Plant Industry, for the time and trouble he has expended in looking out the material.

Chamberlin (p. 201) gave the following key (omitting references to text-figures) to the two named genera of the subfamily TACHARDININAE.*

1. Marginal duct clusters with two closely associated smaller clusters of smaller ducts ; anal fringe not of the usual ligulate type.....*Afrotachardina*, genus n.
- Marginal duct clusters without such auxiliary clusters ; anal fringe of the ligulate type.....*Tachardina*, Cockerell.

The genus *Tachardina* is further subdivided into two groups which may be separated as follows :—

- Anal ring distinctly quadrately sectoried.....Group of *albida*, Cockerell.
- Anal ring unsegmented. Anal tubercle and fringe of very uniform type.....
Group of *decorella*, Maskell

* The terminology adopted by Chamberlin in his monograph has been followed throughout in this paper.

Two species described as new in this paper—*brachystegiae* and *diclipterae*—which are both referable to the *albida* group, possess a short and retracted type of anal fringe bearing a much closer resemblance to that found in the genus *Afrotachardina* than in *Tachardina*.

The nature of the anal fringe and lobes are characters that can only be used with caution. Chamberlin (p. 158) recognises the anal fringe as "of considerable importance in considering the major divisions of the family and of some of the genera but is of only slight specific importance."

It is only possible to determine the true nature of the anal fringe by the examination of a long series of preparations. It would be unwise to lay too much stress on the detailed structure of the fringe, as considerable variation in the shape of the lobes may occur, and the general appearance of the fringe varies according to how the tubercle is lying. Nevertheless, in addition to the short and retracted type of anal fringe referred to above, the study of the species dealt with in this paper shows that two types of long anal fringe can be recognised in the *albida* group. The first type is characterised by the fact that the terminal extremity of the tubercle, as represented by the anal fringe, is broadly rounded. Into this category fall *albida*, *actinella*, *karroo* and *africana*. The other type has a more or less straight anal fringe giving a definitely truncated appearance to the terminal extremity of the tubercle. *T. minor* and *affluens* are of this type. It will be noticed that this latter type is similar to that found in the group of *decorella*, Mask., and the nature of the lobes is also similar. So far as is known at present the first type is confined to the *albida* group.

Chamberlin recorded two species in which there were a pair of internal chitinous processes in the pygidial region—*actinella*, Kll., of the *albida* group and *ternata*, Chamb., of the *decorella* group. It has now been found that both *karroo* and *minor* of Brain possess the same character. In *actinella*, *karroo* and *minor*, the three known African species exhibiting these chitinous processes, the two ovate duct-clusters at the base of the supra-anal plate, found in all the other species of the *albida* group dealt with in this paper, are wanting. There is, however, associated with the anterior halves of the two chitinous processes a longitudinal series consisting of a few circular pores lying parallel to and just outside each chitinous arm. These are best seen in *karroo*, Brain. The pores appear to be characterised by the presence of five or six loculi, and from their position they might conceivably be regarded as rudimentary or vestigial perivaginal pore-clusters. In view of the fact that *T. ternata*, Chamb., which belongs to the *decorella* group, possesses these chitinous processes it does not seem likely, in the present state of our knowledge, that the presence or absence of this character will prove to be of any generic importance, but it will always be a most useful character, in conjunction with others, for specific determination.

There must be a great many more species represented in Africa than those so far collected, and until the fauna is better known it seems inadvisable to suggest any modification of the subdivision of the subfamily TACHARDININAE as laid down by Chamberlin. It appears to be clear that the nature of the anal ring is the character of most fundamental importance and that ultimately the genus *Tachardina* will have to be split into two genera to accommodate the *albida* and *decorella* groups respectively. There are grounds for believing that the subfamily might be subdivided as follows:—

Marginal duct-clusters with two closely associated smaller clusters of smaller ducts; anal ring entire or partly segmented.....*Afrotachardina*, Chamb.

Marginal duct-clusters without such auxiliary clusters

Anal ring entire.....Group of *decorella*, Mask.

Anal ring quadrately sectoried.....Group of *albida*, Kll.

The fact that *Afrotachardina longisetosa*, Newst., has an anal ring that appears to be superficially 10-lobed, and that species with shortened and retracted lobes to the anal fringe of the general type found in *Afrotachardina* have been found in the *albida*

group of the genus *Tachardina*, suggests that it is not improbable that forms may subsequently be found to bridge the gap between *Afrotachardina* and the *albida* group of *Tachardina*. This would clearly cut off the *decorella* group as a distinct genus.

Only two species of *Afrotachardina* are at present known, and in both these species the marginal duct-clusters have two closely associated auxiliary duct-clusters. This character, together with the nature of the terminal aspects of the individual ducts, separate them according to Chamberlin from the other known species of *Tachardina*. It separates them also from the additional species recorded and described here. It will be of considerable interest to note if these characters are consistently present in the genus *Afrotachardina* and absent in the genus *Tachardina* (group *albida*) when additional forms are collected.

*Key to the Southern Rhodesian and South African species of the Genus Tachardina.**

1. Dorsal spine absent.....*albida*, Ckll.
- Dorsal spine present.....2.
2. With a pair of prominent, elongate, longitudinal, internal chitinous processes in the pygidial region.....3.
- Without such structures.....5.
3. With rudimentary legs.....4.
- Without rudimentary legs.....*actinella*, Ckll. & King
4. Anal fringe of the *decorella* type giving a flattened and truncated appearance to the terminal extremity of the anal tubercle.....*minor*, Brain
- Anal fringe of the *albida* type with the terminal extremity of the anal tubercle broadly rounded.....*karroo*, Brain
5. With long anal fringe.....6.
- With short and retracted anal fringe.....9.
6. Anal fringe of the *decorella* type giving a flattened and truncated appearance to the terminal extremity of the anal tubercle.....7.
- Anal fringe of the *albida* type with the terminal extremity of the anal tubercle broadly rounded.....*africana*, sp. n.
7. Brachiae of medium length.....8.
- Brachiae very long.....*affluens* var. *coagulata*, var. n.
8. Brachial plates large and much longer than the dorsal spine.....*affluens* var. *natalensis*, var. n.
- Brachial plates of medium size and shorter than the dorsal spine.....*affluens*, Brain
9. With 16 well defined ventral duct clusters.....*brachystegiae*, sp. n.
- Ventral duct clusters obscure, confined to not more than 6 clusters in the anterior region.....*diclipterae*, sp. n.

***Tachardina albida*, Ckll. (fig. 1).**

Cockerell, 1901, The Entomologist, **34**, p. 249.

Brain, 1920, Cocc. South Africa., Bull. Ent. Res. **10**, p. 126.

Chamberlin, 1923, Bull. Ent. Res. **14**, p. 206.

Material examined.

S. Rhodesian :—On *Acacia* sp. (Leguminosae), Beatrice, 30.iii.29, coll. H. Purdon.

* All the species are of the *albida* group with quadrately sectored anal ring.

S. African :—On "Thorn," Natal, coll. Fuller, Dept. of Agric. No. 72, det. Brain (2 lots of material) ; on ?, Pienaars River, Transvaal, 19.v.06, D. of A. No. 72a, det. Brain ; on *Acacia stolonifera*, Pienaars River, Transvaal, coll. H. K. Munro, det. Hall.

The characters of this species appear to be comparatively constant from the material examined. There is no sign of a dorsal spine in any one of the numerous preparations made and it would seem that the absence of this feature is a constant characteristic of the species.

Chamberlin figures the marginal duct-cluster (p. 203), but he does not show, or refer to in his description, a character that is present in all the individuals seen. Associated with each cluster and enclosing it on the marginal side, but often set at some distance from it, is an arc of smaller ducts consisting of a very regular single row of more or less evenly spaced ducts.

The material on *Acacia stolonifera*, whilst typical in all other respects, showed a much smaller group of pseudospines on the brachial plate. The plates themselves are relatively of much the same size and shape but the area occupied by the group of pseudospines is much smaller. This might well be considered a separate variety of *albida*, were it not that the examination of the species of *Tachardina* dealt with in this

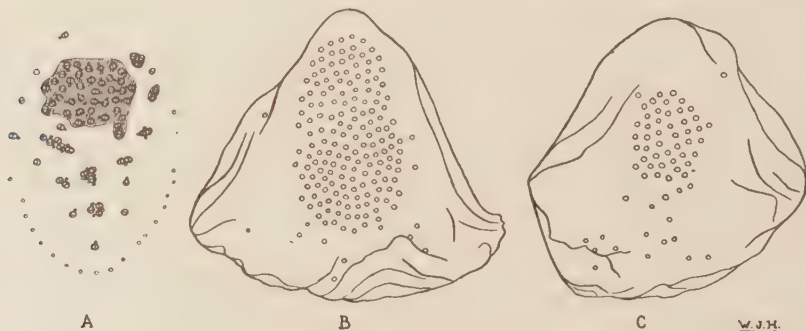


Fig. 1. *Tachardina albida*, Ckll., adult ♀ : a, marginal duct-cluster (x 228) ; b, typical brachial plate (x 228) ; c, brachial plate in specimens from *Acacia stolonifera* (x 228).

paper has shown that the area occupied by, and the number of, pseudospines does vary within the species often very appreciably. Although this material can readily be separated from the other lots of material examined by this difference in the brachial plate, it is highly probable that intermediate forms will be found. For this reason the material has tentatively been assigned to *albida* until it can be decided from the examination of further specimens whether it should be accorded varietal rank or not.

***Tachardina actinella*, Cockerell & King.**

Cockerell & King, 1901, *The Entomologist*, **34**, p. 342.

Brain, 1920, *Cocc. South Africa.*, *Bull. Ent. Res.* **10**, p. 123.

Chamberlin, 1923, *Bull. Ent. Res.* **14**, p. 207.

Material examined.

S. Rhodesian :—On *Royena pallens* (Ebenaceae), Macheke, 12.ix.27, and Mazoe, 23.x.27 ; on *Grevillea* sp. (Proteaceae), Municipal Gardens, Salisbury, 3.xi.27 ; on *Pseudolachnostylis maprounaefolia* (Euphorbiaceae), Darwendale, 14.xii.27. Ex. coll. Dept. of Agric. Salisbury : on "Persimmon," No. 2539 ; on "Pecan," coll. G. W. Marshall, No. 3670 ; and on "native bush," Salisbury, 23.xii.14, No. 667.

S. African :—On "Rose," East London, 21.vi.24, No. A. C. P. 3140, det. Brain ; on ?, Newcastle, Natal, coll. J. J. Mann, No. 71 ; on ?, Durban, 27.ii.13, coll. C. Fuller, No. 71 ; on "Orange," Qumbu, East Griqualand, No. 71 ; on "Pomegranate," Ladysmith, Natal, coll. A. S. Kelly, April 1912, No. 71b. ; on "veld bush," East London, coll. C. P. Lounsbury, Ac. C. 1253.

Rhodesian examples agree very closely with South African specimens with the exception that there is a tendency for the brachial plates to be relatively smaller and the dorsal spine less stout. In South African specimens the spine is sometimes almost pyramidal.

Chamberlin (p. 207) describing the anal tubercle states "fringe very similar to that of *affluens*." I cannot agree with this. He gives a true picture of the anal tubercle and fringe of *actinella* (fig. 7d, p. 202), but it is by no means correct for those of *affluens*. All my preparations show the margin of the fringe in *actinella* to be strongly convex, whereas in the case of *affluens* it is straight or at most only very slightly convex (fig. 5a).

In all the specimens examined the number of marginal duct-clusters present has been found to be 16 and not 14 as quoted by Chamberlin.

Associated with the inner extremities of the two internal chitinous processes are two longitudinal series each containing from one to six circular pores ; these lie parallel and close to the outer margin of each process. In some instances one or two of the pores extend just beyond the inner terminal extremities of the processes.

***Tachardina minor*, Brain (fig. 2).**

Brain, 1920, Cocc. of South Africa., Bull. Ent. Res. **10**, p. 124.

Chamberlin, 1923, Bull. Ent. Res. **14**, p. 211.

Material examined :—Believed to be part of the type material and labelled Dept. of Agriculture, Pretoria, No. 25.

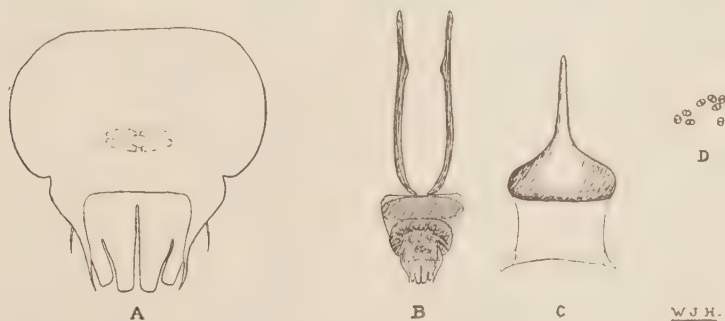


Fig. 2. *Tachardina minor*, Brain, adult ♀ : a, anal tubercle (x 228) ; b, anal tubercle with internal chitinous processes (x 56) ; c, dorsal spine (x 228) ; d, marginal duct-cluster (x 228).

Chamberlin (*l. c.*) did not consider Brain's description sufficiently complete to determine the exact systematic position of this species. The following supplementary details will make this clearer.

A pair of prominent, elongate, longitudinal internal processes are present in the pygidial region, as found in *actinella*. One or two circular pores are to be found at the inner extremity of each chitinous process. Anal fringe with two pairs of lobes on either side of the median cleft of the type commonly found in the *decorella* group but with the anal ring quadrately sectoried. There are no groups of pores at the base of the supra-anal plate. Dorsal spine of an unusual type, being borne on a more or less

prominent membranous pedicel. Sixteen marginal duct-clusters present; these are small, consisting of 6–10 ducts only. Ventral duct-clusters poorly developed and ill-defined, apparently confined to the anterior region. Anterior spiracles with 8–12 small pores; canellae from 3 to 4 times as long as the spiracles, consisting of a loose group of some 16–20 pores. Posterior spiracles with 15–20 small pores in close association. Rudimentary legs, brachial plates and antennae as described by Brain. Brachial plates with pseudospines of the normal type.

This small species is here placed in the *albida* group, but it is by no means typical of that group. The anal fringe, for instance, is of the type found in the *decurella* group, whilst the presence of a pedicel to the dorsal spine and rudimentary legs are characters more commonly found in the genus *Tachardiella*. The nature of the brachial plates, marginal duct-clusters and anal ring, however, place it in the *albida* section of the genus *Tachardina*. It is true that it has a pair of internal chitinous processes to the pygidial region, such as are found in *actinella*, but otherwise it has no claim to close affinity with *actinella*. It is probably closer to *karroo*, Brain, than to any other species of the group, but it differs from that species in the entirely different nature of its anal fringe.

This species is not, as yet, known from Southern Rhodesia.

***Tachardina karroo*, Brain (fig. 3).**

Brain, 1930, Cocc. of South Africa., Bull. Ent. Res. **10**, p. 124.

Chamberlin, 1923, Bull. Ent. Res. **14**, p. 211.

Material examined:—Believed to be a part of the type material and labelled Dept. of Agriculture, Pretoria, No. 324.

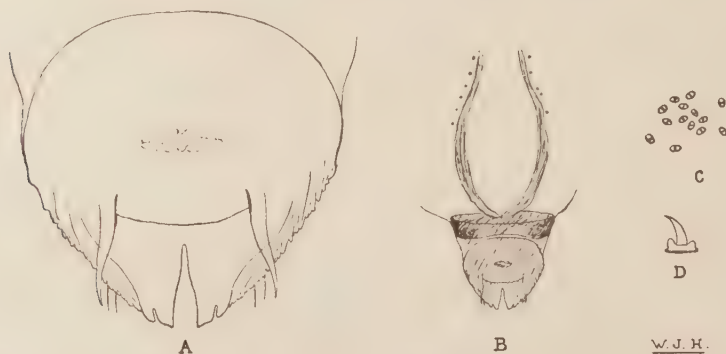


Fig. 3. *Tachardina karroo*, Brain, adult ♀: a, anal tubercle (x 228); b, anal tubercle with internal chitinous processes (x 56); c, marginal duct-cluster (x 228); d, leg (x 228).

The material in the case of this species was extremely heavily attacked by parasites and fungi, but at least two preparations are sufficiently good to show certain important characters not referred to by Brain.

This species has a pair of prominent, elongate, longitudinal internal chitinous processes in the pygidial region such as occur in *actinella* and *minor*. Anal fringe of the *actinella* type with deep and conspicuous median cleft on either side of which is a pair of relatively inconspicuous lobes. Margin of supra-anal plate irregularly serrated. Anal ring of the normal quadrately sectorate type. Alongside the outer anterior half of each chitinous process is a line of some 6–8 circular pores which are more or less evenly spaced. Sixteen marginal duct-clusters present each consisting of a loose group of some 12–16 pores. Ventral duct-clusters present and much better defined than in *minor*, at least in the anterior region where they consist of a loose group of

8–12 pores. Anterior spiracles with a greater number of pores associated with the spiracles, and in the canellae, than in *minor*. Length of the canellae apparently much the same as in *minor* but the pores more crowded. Posterior spiracles also with rather more pores than are found in *minor*. Legs vestigial, represented by minute curved chitinous spines; these are somewhat smaller and less conspicuous than those in *minor*. Brachial plates with pseudospines of normal type, antennae, and dorsal spine as described by Brain. The dorsal spine appears to be of the same type as that found in *minor* but with a shorter and less conspicuous pedicel. Unfortunately the preparations do not show up this character as well as they might.

This species occurs on the same host plant—*Elytropappus rhinocerotis*—as *minor* and in the original material the two species were associated. It seems to be more closely allied to *minor* than to any other species, but the nature of the anal fringe is strikingly different and the brachial plates and marginal duct clusters also exhibit marked differences.

This species has not yet been collected in Southern Rhodesia.

Tachardina sp.

Material examined :—Labelled “ Prince Albert Road, Cape, 17.xi.17, coll. J. C. Faure, host plant not stated.”

This may possibly prove to be a new species, but the material is so heavily attacked by fungi and parasites that it is not possible to determine its characters with a sufficient degree of accuracy. The following details may be recorded.

Female test similar to a small example of *karroo*, spherical, amber-coloured and usually semitransparent. The tests tend to be massed together and a good deal of fusion takes place.

Two internal chitinous processes in the pygidial region, similar to those found in *actinella* and *minor*, are present. The anal fringe appears to resemble that of *karroo*, but the lobes are more pointed. The anal ring is quadrately sectoried. The brachial plates are of the same form and type found in *minor* and *karroo*, the number of pseudospines present being intermediate between the two. The marginal duct-clusters are small and with few pores, of the type found in *minor*. Spiracles as in *karroo*. Character of the dorsal spine not clear. Rudimentary legs present.

This species is clearly closely allied to *minor* and *karroo*. It comes closest to *karroo*, from which it appears to differ in the more pointed nature of the lobes of the anal fringe, the smaller marginal duct-clusters and the fewer pseudospines on the brachial plate. More and better material is necessary to determine whether it is referable to *T. karroo*, Brain—as it may possibly prove to be—or a distinct species.

Tachardina africana, sp. n. (fig. 4).

Tachardia decorella, Mask., Brain, 1920, Cocc. South Africa., Bull. Ent. Res. **10**, p. 125 (Misidentification).

“ “ Chamberlin, 1923, Bull. Ent. Res. **14**, p. 212.

S. Rhodesia :—On *Acacia* sp. (Leguminosae), Melfort, 11.vi.28.

S. Africa :—On *Acacia melanoxylon*, Pretoria, coll. D. Gunn, 7.iii.14, Dept. of Agric. Pretoria No. 323, det. Brain *T. decorella*, Mask.

Test almost circular, squat dome-shaped, flattened on top with usually sixteen distinct yellowish white obtuse ridges radiating from the apex to the margin. Tests may be separate, but they are more often so close together that they coalesce into masses of varying sizes. Colour dark brown. Diameter, 3 mm.; height, 2 mm.

Antennae of doubtful number of segments, three usually apparent, but some preparations show a comparatively long slender and extremely hyaline basal segment.

Brachiae long and membranous throughout. Brachial plates relatively large, sub-triangular with a group of numerous pseudospines which usually do not extend into the basal third of the plate. Anterior spiracles of normal type with several pores and canellae of scattered star pores twice, or rather more, as long as the spiracle itself; posterior spiracles as usual, associated with a group containing several pores. Dorsal spine very stout at the base but tapering rapidly for the first half of its length; it is generally shorter than the brachial plate and, although it may in some instances be of approximately the same length, it is never longer. Marginal duct-clusters 16 in number, each consisting of one or two large clusters and some smaller clusters, the entire group being enclosed by a well-defined arc-shaped series of single small pores. Ventral duct-clusters, 16 in number, each consisting of 10–20 very loosely grouped pores.

Supra-anal plate as long as broad; anal fringe, similar to that found in *actinella*, with a large median lobe and a smaller lateral lobe on each side of the median cleft and a pair of stout spines just beyond the lateral lobe. Anal ring quadrately sectoried. Anal ring setae projecting only just beyond the anal fringe. At the base of the supra-anal plate and on either side of it there is an ovate group of small pores such as are found in a similar position in *albida*.

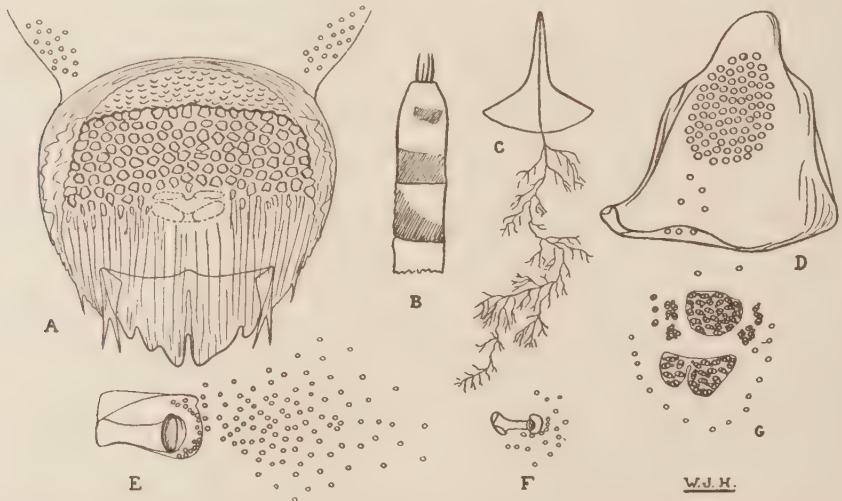


Fig. 4. *Tachardina africana*, sp. n., adult ♀: a, anal tubercle (x 228); b, antenna (x 228); c, dorsal spine (x 114); d, brachial plate (x 228); e, anterior spiracle and canella (x 114); f, posterior spiracle (x 114); g, marginal duct-cluster (x 228).

Chamberlin (*l. c.*) suggested from a study of Brain's description that the identification of this species as *decorella*, Mask., was incorrect. Part of the original material recorded by Brain as *decorella*, Mask., and four slides similarly labelled and bearing the same collection number have been examined and bear out Chamberlin's contention that this could not be *decorella*, Mask. Rhodesian material is identical with that from South Africa, and it proves to be distinct from all the other known species from Southern Africa.

Individual tests are practically indistinguishable from those of *actinella* and *brachystegiae*, but in this species there is a marked tendency for the tests to coalesce into masses.

This species appears to be most closely allied to *albida* from the nature of the anal tubercle and marginal duct-clusters, although it is very different from it in several

respects. *T. brachystegiae* has a similar type of marginal duct-cluster, but the anal fringe is of an entirely different type.

***Tachardina affluens*, Brain (fig. 5).**

Brain, 1920, Cocc. of South Africa., Bull. Ent. Res. **10**, p. 125.

Chamberlin, 1923, Bull. Ent. Res. **14**, p. 206.

Material examined:—On *Athanasid* sp., Hex River, Cape, coll. C. W. Mally, 15.viii.02, Cape No. 1505, Dept. of Agric. Pretoria, No. 74 on "Pride of India" (*Lagerstroemia indica*), Hatfield, Pretoria, coll. C. P. Lounsbury, July 1917, Dept. of Agric. Pretoria, No. 76a. (N.B.—In transmitting this material Mr. H. K. Munro states "Label says 'Pride of India' but in Brain's notes plant name is changed to 'Euclea'"); on ? *Cestrum* sp., Pretoria, coll. H. K. Munro, 22.i.35, det. Hall.

The first two lots of material quoted above were determined by Brain, but presumably neither is part of the type material which carried the collection number 76. It appears to be a variable species in some respects. Chamberlin (*l. c.*) states dorsal spine "distinctly longer than brachial plate." In the Hex River material the spine was always either as long as or longer than the brachial plate, but in the Pretoria material it was very often shorter than the brachial plate. There also appears to be some variation in the relative size of the brachial plate.

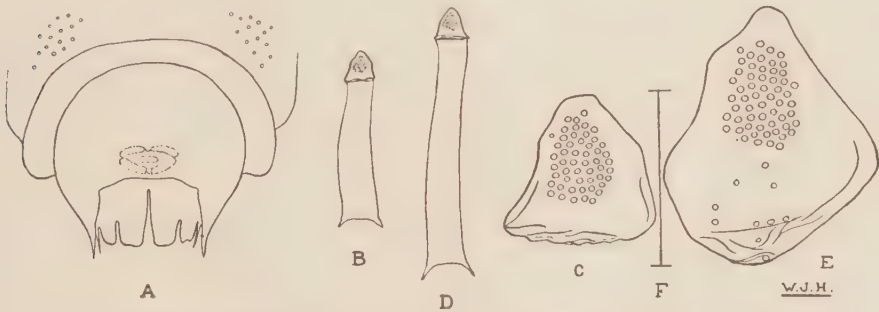


Fig. 5. *Tachardina affluens*, Brain, adult ♀: a, anal tubercle (x 228); b, brachia (x 45); c, brachial plate (x 228). *T. affluens* var. *coagulata*, var. n., adult ♀: d, brachia (x 45). *T. affluens* var. *natalensis*, var. n., adult ♀: e, brachial plate (x 228); f, length of dorsal spine of both *affluens* and *affluens* var. *natalensis*, var. n. for comparison with c and e (x 228).

If the material examined is really referable to *affluens*, then I cannot agree with Chamberlin that apparently no true pseudospines to the brachial plates are present but that "they appear to be entirely replaced by true setae." The spines in this material lie in such a position that it is more difficult to make out their true structure than in any of the other species examined with the exception of *diclipterae*. A few spines at the apex of the group nearly always reveal the typical 5 or 6 loculi of the pseudospine when viewed from a vertical position. The examination of a long series of preparations shows that the group consists of pseudospines of apparently the typical form with a few odd true spines at intervals round the margin. Chamberlin mentions that his material was poor and that consequently he was unable to make quite certain of the true nature of the spines. It is probable that he was misled by the fact that the pseudospines rarely lie in a vertical position in this species and when viewed from an angle they do bear a strong resemblance to true spines.

Owing to the pooriness of his material Chamberlin was also unable to be certain how many marginal duct-clusters are present. There are 16.

Chamberlin, when describing *T. actinella*, mentions that the anal fringe in *actinella* is very similar to that of *affluens*. It has already been pointed out when dealing with *actinella* that the material examined does not substantiate this view. The fringe in *affluens* as representing the terminal extremity of the anal tubercle is flattened and gives a truncated appearance to the tubercle (fig. 5a), whereas in *actinella* it is broadly rounded. The nature of the lobes also is quite different.

Neither this species nor the two varieties of it described below have as yet been collected in Southern Rhodesia.

***Tachardina affluens*, Brain, var. *coagulata*, var. n. (fig. 5d).**

On ? *Hakea* sp., Brits, Transvaal, coll. Mrs. R. Martin, 1932, and on "Persimmon," Warmbaths, coll. R. J. B. Meek, June 1931.

This variety differs from *affluens*, Brain, in the following respects:—(1) The tests have a strong tendency to occur in masses and bear a close resemblance to *albida*, Ckll.; (2) the test and adult female is larger; (3) the brachiae are very much longer, being from half as long again to double the length of the brachiae in *affluens*.

This species bears a very close resemblance to *affluens* under the microscope, and it is only by its greater size and very much longer brachiae that it can be separated. These characters in themselves would hardly warrant separating it from *affluens* were it not that the tests are so strikingly different. In *affluens* rarely more than two or three tests are fused together, whereas in this variety many tests coalesce to form large masses which encircle the twig to a greater or lesser extent. It may be that with the collection of additional material of *affluens* it will be found that in cases of heavy infestation fusion of the tests, such as is found in the variety *coagulata*, may take place, but for the time being this material must be considered a variety of *affluens*, Brain.

***Tachardina affluens*, Brain, var. *natalensis*, var. n. (fig. 5e).**

On *Ficus* sp., Pietermaritzburg, Natal, coll. A. Kelly, 1910.

This variety differs only from *affluens*, Brain, in the consistently larger brachial plates. They may be as much as nearly twice as long as those in *affluens* and the group of pseudospines occupies a relatively much smaller area of the plate. The brachial plate is always much longer than the dorsal spine.

Although this material is so very similar to *affluens*, it cannot be assigned to that species on account of the striking and consistent differences in the nature of the brachial plates.

***Tachardina brachystegiae*, sp. n. (fig. 6).**

On *Zizyphus jujuba* (Rhamnaceae), Glendale, 20.xi.27; *Cestrum* sp. (Solanaceae), Mazoe, 28.ii.28; *Berlinia globiflora* (Leguminosae), El Dorado, 29.iii.28; *Acacia* sp. (Leguminosae), Mazoe, 8.iv.28; *Brachystegia* sp. (Leguminosae), Mazoe, 23.i.29 and 27.i.29; on an unknown host plant, coll. A. Sealy Allin, 12.v.31, per M. C. Mossop of the Department of Agriculture, Salisbury; on "Custard Apple," Salisbury, 1910, and *Hibiscus* sp., Salisbury, May 1931, ex. coll. Dept. of Agric., Salisbury.

Tests similar in all respects to that of *actinella* but the colour is usually dark brown. As the colour is very dark the tests are practically indistinguishable from those of *actinella*. Diameter, 3 mm.; height, 2 mm.

Antennae as figured for *africana*, apparently of three segments, of which the terminal segment is twice as long as the second and the basal segment is so hyaline as to be observed only with difficulty, but there are indications that it may be as long as the terminal segment. Brachiae long and membranous throughout; brachial

plates subtriangular, with the usual group of pseudospines. Anterior and posterior spiracles as in *africana*, but the pores are slightly fewer in each case; the canellae much the same length as in *africana*. Dorsal spine stout at the base tapering very rapidly for the first third of its length; either the same length as, or more usually longer than, the brachial plate. Marginal duct-clusters, 16 in number, and ventral duct-clusters as in *africana*. Supra-anal plate slightly longer than broad. Anal fringe retracted, consisting of a pair of flatly rounded median lobes separated by a median cleft; on either side of the median lobes is a similar but usually rather smaller lobe, the fringe being terminated laterally on each side by two stout spines. The terminal margin of the lobes is variable; they are practically always faintly serrated and all stages can be seen from the faintest serrations to deep indentations, the lateral pair of lobes showing very much more variation than the median pair. Anal ring quadrately sectoried with the anal ring setae projecting well beyond the fringe. The anal fringe is usually superimposed on the anal ring, or *vice versa*, in most preparations and consequently it is not easy to make out its true character. At the base of the supra-anal plate and on either side of it, occurs an ovate group of small pores such as are found in a similar position in *africana*, *albida* and other species.

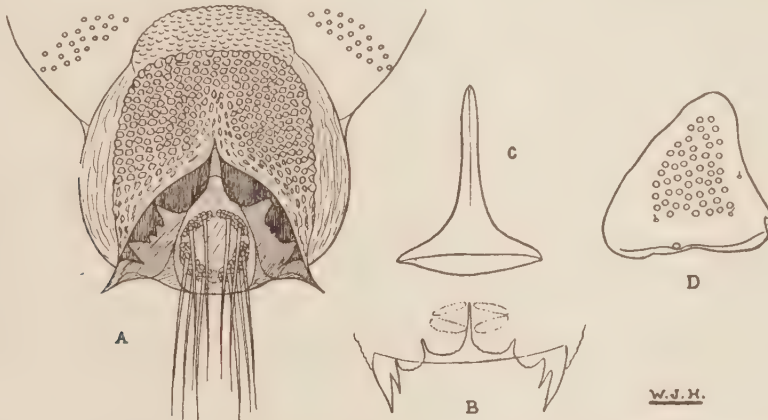


Fig. 6. *Tachardina brachystegiae*, sp. n., adult ♀: a, anal tubercle (x 228); b, alternative view of anal fringe (x 228); c, dorsal spine (x 228); d, brachial plate (x 228).

This species is almost indistinguishable to the naked eye from *actinella*. It appears to be relatively common in the Colony of Southern Rhodesia, but so far it has not been collected elsewhere. Under the microscope it resembles *africana* in many respects but differs from that species in the relatively much smaller brachial plates and longer but less stout dorsal spine; the arrangement of the pseudospines on the brachial plate is also different. The most important difference, however, lies in the anal fringe, which is short and retracted, as distinct from the long protruding form found in *africana*.

***Tachardina diclipterae*, sp. n. (fig. 7).**

On *Dicliptera Rogersii* (Acanthaceae), Inyazura, 6.vi.28. On the stems just below ground-level and on the roots.

Test of adult female semitransparent, reddish and globular, but flattened dorsally. No regular flutings, but usually up to five shallow radiating grooves can be seen. There is a distinct tendency for the tests to coalesce into masses. Diameter, 2-3 mm.; height, 1-1.75 mm.

Antennae obscurely three-segmented. Brachiae of moderate length; brachial plates subtriangular with numerous pseudospines. Anterior and posterior spiracles

of normal form; canellae of scattered pores two to three times the length of the spiracle, posterior spiracles with a small group of some 12-15 pores. Dorsal spine of the usual type expanding suddenly from a point about two-thirds of its length from the apex into a stout and flattened base; it is very slightly shorter than the brachial plate. Marginal duct-clusters 16 in number, each consisting of some 30-40 pores. There is usually one small group of pores within the cluster and a few pairs and threes, but otherwise the pores are separate; there is evidence of an encircling arc of smaller pores, but this is not so regular or well defined as in *africana*, *brachystegiae* and *albida*. There are also never such large groups of pores within the cluster as are found in *africana* and *brachystegiae*. Apparently there are only, at most, six ventral duct-clusters and these are confined to the anterior region of the body; these are inconspicuous and consist of 12-18 small ducts. Supra-anal plate about as long as broad. Anal fringe of the short retracted type found in *brachystegiae* and, so far as can be seen, of exactly the same form and equally difficult to see on account of the anal ring

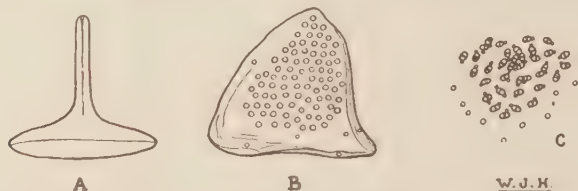


Fig. 7. *Tachardina dichipterae*, sp. n., adult ♀: a, dorsal spine (x 228); b, brachial plate (x 228); c, marginal duct-cluster (x 228).

and setae. Anal ring quadrately sectoried with the anal setae projecting well beyond the fringe. At the base of the supra-anal plate and on either side of it appears an ovate group of small pores as in *albida* and other species.

This species with its short type anal fringe is obviously closely allied to *brachystegiae*. It differs from that species in the appearance of the test, the character of the marginal duct-clusters and the reduced number of ventral duct-clusters.

The pseudospines on the brachial plates are similar to those of *affluens* and equally difficult to make out. As in the case of *affluens*, the pseudospines nearly always lie at an angle and simulate true spines, but where a vertical view is obtained the typical 5 or 6 loculi can be seen.

It is interesting to note that this species was confined to the roots and subterranean parts of the host plant. This appears to be most unusual, for Chamberlin does not record a single species from below ground in his monograph on the LACCIFERIDAE.

THE ECONOMIC POSSIBILITIES OF AEROPLANE DUSTING AGAINST FOREST INSECTS.

By IVAR TRÄGÅRDH.

Ten years have now elapsed since the first dusting operations by aeroplanes were carried out against forest insects in Germany. It is therefore a tempting task to try to review the development of this modern method of fighting forest insects and to formulate, at least tentatively, some fundamental conceptions regarding the specific conditions which must be fulfilled before this method is resorted to.

In order to accumulate first-hand information regarding the present status of aeroplane dusting (or dusting from the ground) I sent a circular to the leading forest entomologists in those countries in Europe and North America where it was to be expected that this method had been used, asking quite a number of questions, amongst which only a few are of interest here, *viz.* the name of the insects which were treated, the area of the forest treated, the amount of dust used, and the risk of other animals suffering from the poison.

Survey of the dusting operations carried out against forest insects in Europe during 1925-34.

The following tables give the result of this inquiry, from which it is evident that during the last decade in Europe about 100,000 hectares have been dusted either from aeroplanes or from the ground, the former method being used about twice as often as the latter. The use of a ground-duster presupposes both that the ground is fairly even and that the trees are planted in rows between which the vehicle can move. Furthermore it is used when the areas are fairly small, not exceeding 100 hectares.

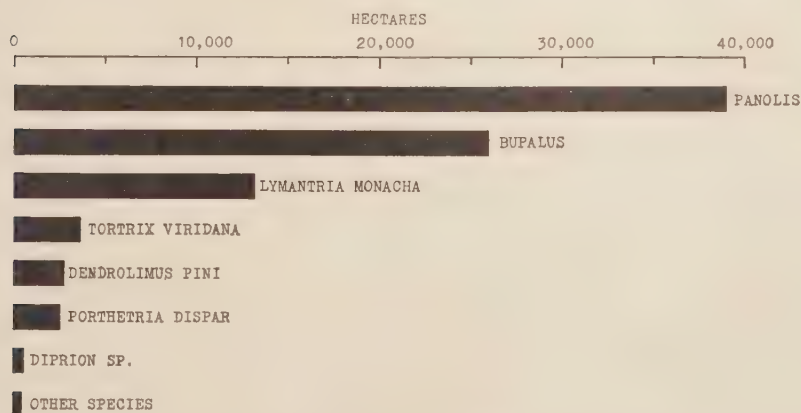


Fig. 1. Survey of arsenic dusting in Europe during the ten-years period 1925-1934, arranged according to the different species of insects. The numbers indicate the total area for each insect.

SUMMARY OF DUSTINGS HITHERTO CARRIED OUT.

Germany (according to Eidmann).

Dusted area in hectares.

	Injurious insects	1925	1926	1927	1928	1929	1930	1931	1932	Totals
Dust- ing from aero- planes	<i>Lymantria monacha</i>	1,602	3,350	2,596	2,865	—	—	—	—	10,413
	<i>Bupalus piniarius</i> ...	690	1,390	—	10,583	1,305	—	—	—	13,968
	<i>Panolis griseovariegata</i>	—	—	—	—	—	—	6,687	2,508	9,195
	<i>Diprion</i> sp. ...	—	—	276	192	—	—	—	—	468
	<i>Tortrix viridana</i> ...	—	1,980	—	—	—	—	—	—	1,980
	TOTALS ...	2,292	6,720	2,872	13,640	1,305	—	6,687	2,508	36,024
Dust- ing by ground dus- ters	<i>Lymantria monacha</i> ...	—	—	—	—	—	—	34	180	214
	<i>Bupalus piniarius</i> ...	—	—	—	—	2,120	59	—	—	2,179
	<i>Panolis griseovariegata</i>	—	—	—	—	—	489	1,257	400	2,146
	<i>Diprion</i> sp. ...	—	—	30	—	—	—	37	—	67
	<i>Cheimatobia boreata</i>	—	—	—	—	—	226	—	—	226
	<i>Lyda</i> sp. ...	—	—	—	—	—	199	162	—	361
	<i>Dendrolimus pini</i> ...	—	—	—	—	—	—	60	—	60
	TOTALS ...	—	—	30	—	2,120	973	1,550	580	5,253

Poland (according to M. Nunberg).

	Injurious insects	1927	1928	1930	1931	1932	1933	1934	Totals
Dust- ing by ground dus- ters	<i>Bupalus piniarius</i> ...	7,000	—	—	—	—	—	—	7,000
	<i>Panolis griseovariegata</i> ...	—	—	—	—	—	15,000	—	15,000
	TOTALS ...	7,000	—	—	—	—	15,000	—	22,000

Russia (according to Rudnev).

Injurious insects	1926	1927	1928	1929	1930	1931	1932	1933	1934	Totals
<i>Lymantria monacha</i> ...	640	—	—	—	—	—	—	—	—	640
<i>Dendrolimus pini</i> ...	—	—	—	1,200	—	—	—	—	1,500	2,700
<i>Porthetria dispar</i> ...	—	—	—	—	—	—	900	1,500	150	2,550
<i>Panolis griseovariegata</i>	—	—	—	—	—	7,500	—	—	—	10,300
<i>Bupalus piniarius</i> ...	—	—	—	—	2,800		—	—	—	
<i>Tortrix viridana</i> ...	—	—	1,500	—	—	—	—	—	—	1,500
TOTALS ...	640	—	1,500	1,200	2,800	7,500	900	1,500	1,650	17,690

In Czechoslovakia, according to Komarek, 4,240 hectares have been dusted, 2,000 attacked by the nun-moth and 2,240 by *Panolis*, 3,240 hectares have been dusted from aeroplanes, the rest by ground-dusters.

In Austria, according to Schimitscheck, only 135 hectares, attacked by *Panolis*, have been dusted from the ground.

According to reports received, thus, including 1934, the following areas have been dusted from aeroplanes or by ground-dusters :—

Germany	...	...	about	50,000	hectares
Russia	...	...	"	17,690	"
Poland	...	...	"	22,000	"
Czechoslovakia	...	...	"	4,240	"
Austria	...	...	"	135	"
<hr/>					
Total	...	...	"	94,065	"

Of this area the following has been dusted from aeroplanes :—

In Germany	...	...	about	43,000	hectares
„ Russia	...	...	"	17,690	"
„ Czechoslovakia	...	...	"	3,240	"
<hr/>					
Total	...	...	"	63,930	"

The danger of calcium arsenate dusting to the fauna of the forest.

Whenever this method has been contemplated there has always been a great outcry in the newspapers, especially from nature-lovers, who feared that not only the injurious insects but also the rest of the wild life, birds, deer, rabbits, etc., might perish.

It is true that some cases of poisoning have occurred, notably at Haste, Germany, in 1925. But this was in the first years when great amounts of dust were used and the arsenic content was about 40 per cent. When subsequently smaller dosages of 11–18 per cent. arsenic acid were used, no cases of poisoning occurred, not even in Germany where up to date over 2,000 tons of dust have been distributed in the forest. Escherich has therefore emphasised that the apprehension that the birds or other animals of the forests would perish, or at least suffer, from the dusting has proved to be unfounded.

Some ideas are, however, too deeply fixed in the human mind to be uprooted by even well established facts. It is therefore necessary to dwell at some length on this side of the topic—the evidence of the harmlessness of the dusting to the wild life of the forest. Nobody denies that arsenic acid is toxic to both man and other higher animals. For this reason the forest to be dusted is often closed. But, on the other hand, the forest entomologist most emphatically denies that the dusting, when carried out properly, involves any danger to man or other animals, because the dust is distributed in an even layer which is so exceedingly thin that it is necessary to use a microscope to see it.

According to German researches the mean lethal dosage of arsenic acid is : for cattle 15–30 gram ; horses, sheep, goats 8–10 gram ; pigs 0·5–1 gram ; fowls 0·1–0·15 gram. Eidmann has made the following calculation concerning the number of poisoned larvae necessary to kill a small bird. A Lepidopterous larva of the size of a winter-moth larva dying when it has swallowed 0·0000001 gram and the lethal dosage of a singing-bird being 0·005 gram, it follows that the bird must devour 50,000 poisoned larvae in order to get this dosage. This is extremely unlikely to happen for the reason that the birds prefer living larvae to dead ones. Eidmann has proved that even birds that are well known as voracious insect-eaters do not

come to any harm when living in a dusted forest, by observations at Strachate near Breslau, where the forest was dusted against *Tortrix viridana* and *Cheimatobia boreata* and five nests of starlings were closely watched.

In order to throw light upon the topic in question I give an account of the information I have received in answer to my inquiries.

Swaine, in Canada, writes that some mortality to rabbits was noticed in Canada that could be assigned to dusting, but none to larger wild animals. In one case two cows were killed, possibly as a result of dusting, but in this case the pilot disobeyed instructions and emptied his hopper at the end of the operation over a pasture field.

Komarek, Czechoslovakia, writes briefly, that when the dusting operation is going to take place it has to be made known in good time so that cattle are not allowed to feed in the dusted area, and bee-hives have to be removed.

Nunberg, Poland, writes that all those living in the neighbourhood were warned as to the dusting, that pasturage was prohibited and that the forest-roads were closed; further, placards with pictures of death-skulls were placed along the edges of the wood. No complaints were received.

Escherich, Germany, writes that in dusting operations no precautions were taken regarding wild animals, birds, etc. It has, moreover, become evident that by competent treatment the risk of poisoning wild animals and birds within and in the environs of the dusted areas is rather small and can be left out of account. Bees must be removed at least 10 km. from the forest and are not allowed in until it has been ascertained that there is hardly any arsenic acid still left on the plants.

Schimitschek, Austria, writes that no accidents have occurred in Austria. It has not even been considered necessary to take any particular precautions regarding other animals. Nor was it necessary to remove the bees, because in the autumn, when the dusting operation was carried out, the pine wood did not contain any food for the bees. In spite of thorough searches no dead mammals or birds were found. The dusting did not even cause any injury to the ant-hills, nor to beetles, flies or parasitic Hymenoptera. Only *Calosoma sycophanta*, which feeds on caterpillars, was killed.

Modern efforts to replace calcium arsenate by contact poisons.

Although, as pointed out above, the dangers of dusting forests with calcium arsenate have been greatly exaggerated, there is a decided tendency, especially in Germany, to find substitutes for this poison. The reason for this seems partly to be the difficulty of overcoming the obstacles presented by the arsenic psychosis, but it is mainly due to other considerations.

It cannot be denied that all stomach poisons when used on a large scale in forests are from a certain point of view inferior to contact poisons such as pyrethrum and rotenone. In order to be effective a stomach poison must possess a number of properties, such as, for instance, the ability to adhere to the foliage of the trees until it is devoured by the larvae. But even if the adhesiveness is satisfactory, this is not enough to ensure a good result, because much depends on the length of time that elapses before the larvae feed on the poisoned leaves, and this again depends upon the relation between the number and size of the feeding larvae at the time when the operation is carried out, and the total surface of the leaves or needles and its consistence.

As a matter of fact one has two alternatives to choose between, each with its advantages and drawbacks. If one spreads the dust when the larvae are very small, it takes a much smaller amount of poison to kill them, but it is imperative that the covering layer should be distributed over all the foliage, because if not, it may be that so much time elapses before the larvae have a chance to get poisoned that

rain has washed away the arsenate. If, on the other hand, the dust is spread after the larvae are half-grown or more, the foliage has perhaps already been severely injured and (which is also very detrimental to the success of the operation) does not catch enough of the dust but lets it through to the ground.

These difficulties are partly removed when a contact poison is used, because the action is then direct and follows as soon as the dust comes into contact with the cuticle of the larvae. This is all to the good, but on the other hand, it would seem that very dense foliage would greatly impede the passage of the dust through the crowns of the trees and prevent it from falling upon the larvae.

Probably financial considerations regarding the possibility of obtaining the requisite poisons at reasonable prices will decide which method will be used. In Sweden the question is easily settled, because surplus quantities of arsenic are produced in this country, whereas the other poisons must be imported.

In Germany several preparations containing a mixture of pyrethrum and rotenone have been used during the two last years with great success.

Comparison between the different methods of dusting.

There seem to be two different ways of dusting in Europe, one used in Germany, Poland, Austria and Czechoslovakia, the other exclusively used in Russia, and apparently not known in other countries.

In Germany at least 50 kilograms of dust per hectare is used and the mean cost per hectare is 50 goldmarks, which is equivalent to 75 Swedish crowns. This high expenditure is absolutely prohibitive in Sweden, unless it is a question of stamping out at all costs an outbreak of a very dangerous pest, as for instance the nun moth in its initial stage.

Fortunately it is possible to lower the cost of dusting operations by having recourse to the Russian method. The Russians have endeavoured to reduce the cost of the dusting operations in a way that is as simple as it is ingenious. They start the dusting as soon as possible after all the eggs have hatched. The smaller the larvae are, the smaller is the amount of poison which is required to kill them. Hence the Russians do not use more than 5–15 kilograms of dust per hectare, the mean quantity being 8 kg., 5–6 kg. being quite sufficient against *Panolis griseovariegata* and *Diprion*. But on the other hand, calcium arsenite (70 per cent. As_2O_3) is used pure, not diluted with any inert substance.

With a load of 250 kg. a Russian aeroplane is able to dust 20–25 hectares during one trip, which is 4–5 times as much as with the German method. As the filling of the hopper and the flight to and from the forest to the landing-place require much time, the gain made by using a smaller dose is very considerable. According to Rudnev an aeroplane may make 10–12 trips in the early morning hours—which are preferred because at that time there are no ascending air-currents above the forest—and 4 trips in the afternoon, which is equivalent to a treatment of a maximum of 400 hectares per diem and an average of 200 hectares.

A calculation of the amount of arsenic acid spread out per square metre by these two methods shows that the Russian method, using 8 kg. per hectare of 70 per cent. As_2O_3 , is equal to 0.56 gram per square metre, while the German method, using 50 kg. per hectare of 15 per cent. As_2O_3 , is equal to 0.75 gram per square metre. It is evident that the higher toxicity and greater adhesive power of the calcium arsenite fully compensates for the smaller quantity used.

The chief reason why I took steps to acquire information regarding the present status of dusting in forests was the possibility of applying this knowledge to the entomological conditions in Swedish forests. But quite apart from the specific conditions of Sweden, which must be taken into consideration when calculating the pros and cons in aeroplane-dusting, there is every reason to dwell upon some

aspects of the subject which are of fundamental importance. The problem of calculating the profit gained by aeroplane-dusting consists in estimating the cost of the operations and weighing it against the profit gained by dusting which is equal to the loss that would have been caused by the insects if nothing had been done.

The injurious activity of the insects in question consists of their devouring the assimilating parts of the trees, the leaves or needles. The effect of this, especially if the defoliation is repeated during two consecutive years, is often that the trees die, their dying often having been accelerated by the attacks of bark-beetles in the weakened trees. If the injury is less severe the result may be only a decrease in the growth of the tree. These are the two main classes of injury, but there are also others, such as the deterioration in the shape of the crown.

It does not present any difficulties to estimate the number of cubic metres represented by the dead trees or to measure the reduction of the annual rings and estimate the same in cubic metres. But the real difficulty is to estimate what these losses are worth in money.

It is not possible to lay down any fixed rules for the conversion of the damage into cash, but every instance must be treated individually, because many factors are involved which may vary considerably in different cases. It seems to me that it is a very important side of the work against injurious forest insects (hitherto much neglected) to devise a plan both of investigating minutely the actual amount of injury sustained by the forest and of estimating the loss in money.

In order to offer some contribution towards the solution of this problem some actual cases are given here.

During the years 1898–1902 the nun moth (*Lymantria monacha*) in Sweden attacked some 9,000 hectares of mixed pine-spruce forest, of which 3,000 hectares of spruce forest was killed. The economic loss was calculated to be about 1,000,000 Sw. crowns, to which sum must be added the cost of the campaign, which was 390,000 Sw. crowns, making a loss of about 466 Sw. crowns per hectare. Assuming that at that time modern aeroplane dusting had existed and that the pest had been detected early enough to make it possible to stamp out the infestation by this method during 1898, when only about 800 hectares were infested, it is evident that even if the campaign had cost 50 Sw. crowns per hectare, or in all 40,000 Sw. crowns, it would have been a great success from a business point of view.

On the other hand, the small isolated attack of the nun moth in N.E. Scania in 1915–1917 corroborated the view that the pine suffers far less than the spruce from this insect. Investigation of two sample plots laid out in this forest revealed the fact that the subsequent dying of a few small and stunted pines, in a condition typical for pines which succumb to pine beetles, had nothing to do with the attack of the nun moth.

In this instance the injury was restricted to a decrease in the growth. An examination, made in 1924, elicited the fact that this decrease amounted to 0.01 cu. m. in a tree of average size 13 m. high and 17 cm. BHD. As the stand contained 1,100 trees per hectare, this decrease is equal to 11 cu. m. per hectare or 14.5 stacked cu. m. Assuming that the trees were cut up for fuel and basing the calculation on a net price of 3 Sw. crowns per cu. m., the loss caused by the nun moth is equal to about 43 Sw. crowns per hectare.

The outbreaks of the pine-looper (*Bupalus piniarius*) are far more common than those of the nun in Sweden. The attacks occur exclusively in the eastern part of S. Sweden, i.e. in the driest parts and chiefly after a period of some years of greatly diminished precipitation, facts which seem to warrant the assumption that it is the detrimental influence of the dry condition of the soil which eliminates the checking effect of the entomophagous fungi of the soil on the hibernating larvae. The outbreaks generally stop after two years.

The effect of the defoliation of the pine tree by the pine-looper in 1916-1917 has been investigated on several sample plots. In Sörby crown forest an examination in the spring 1918 revealed the fact that the pine beetle was breeding in 4 per cent. of the trees and had without success tried to attack 10 per cent., the remaining trees being unattacked. The trees attacked by the pine beetle were, however, of the type which is doomed to succumb sooner or later in this way. Hence their death cannot be put down as a consequence of the previous defoliation by the pine-looper.

A second investigation, made ten years later, in 1927, revealed however the fact that the influence exerted by the defoliation continues for several years and that at this time 31 of the remaining 109 trees of the sample plot (or 28.4 per cent.) had died. Based on the measurements of the trees it is possible to convert this percentage into cubic metres, showing that of the total 21.88 cu. m., 7.92 (or 36.2 per cent.) had died.

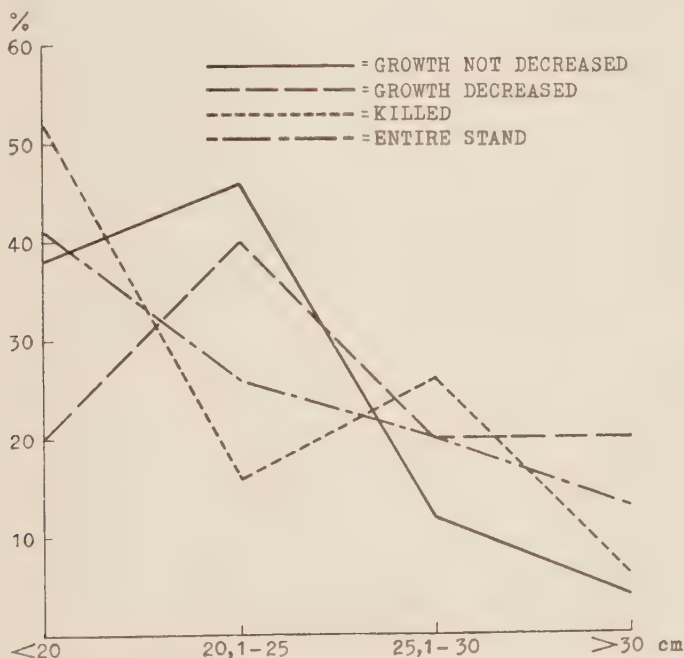


Fig. 2. Analysis of a pine sample-plot in Sörby crown forest after an attack by the pine-looper in 1915-17. The trees are divided into 4 dimension classes.

It is of great interest to investigate the distribution of these dead trees in the different size-classes of the stand. The graph (fig. 2) illustrates the result of these investigations and the result of an analysis of the decrease in growth of the remaining living trees.

It is evident that the distribution of the dead trees follows fairly closely the general trend of the trees of the whole plot, with the exception that the more slender trees and the next biggest trees dominate. The preponderance of the former is easily explained by the action of the pine beetle and has probably nothing to do with the pine-looper. If we subtract the 7 dead pines, the BHD of which is less than 15 cm., these represent only 0.5 cu. m., and the figure given above must be reduced to 7.42 cu. m.

The growth during 1910–1924 was investigated in 38 of the remaining trees. Based on the measurements of the width of the annual rings it was possible to distinguish between two groups: one, comprising 15 trees, exhibited a successive decrease, starting in 1914 and continuing, with an interruption in 1917 to 1920, when a steady increase followed; the other group, comprising 23 trees, showed a steady increase from 1914 to 1917, and afterwards the growth became approximately constant.

It is impossible to judge what forces have been active in these instances. It is obvious that during the growth of a stand, involving as it does the action of the soil conditions, the climatic conditions on the trees and the interaction between the trees when competing with one another, some will be more successful and by growing more vigorously will not only out-distance the others, but by their very increase will deteriorate the conditions for the less successful. It may be that such a process is depicted by the two curves. The fact that their general trend is quite different from the other two curves seems, at all events, to prove that these phenomena have nothing to do with the defoliation of the pine-looper, and at the same time show how wary one must be when drawing conclusions from measurements of growth.

The influence of the attack of the pine-looper was also investigated in another locality near Västervik, where 30 per cent. of the cubic mass had died.

It now remains to translate this loss into hard cash. For this purpose it is convenient to base the calculations on a single pine tree of medium size, *e.g.* 20 m. height and 30 cm. BHD. We assume: (1) that such a tree is cut down during the regular thinning operations and cut into logs and pulp-wood, quality unassorted; (2) that it died owing to the attack of bark-beetles, etc., following on a defoliation by the pine-looper and (a) is cut into logs and pulp-wood, which on account of blue-stain is quinta, or (b) is converted into fuel.

1. In the first instance the yield is

(a) One 17ft. \times 9in. log, 53 öre per cubic foot = 7.51×35 öre = 3.98

(b) One 19ft. \times 7in. log, 43 öre per cubic foot = 5.08×43 öre = 2.18

(c) One 14ft. \times 7in. pulpwood piece à 22 öre per

cubic foot = 1.9×22 öre = 0.42

Total 6.58 Sw. cr.

2. In the second instance with the reduction for V quality the total price is 5.17.

3. When the tree is cut up for fuel the yield is 0.93 cu. m. at 3.50 or 3.32.

From these prices must, however, be deducted the cost of production, which in the case of logging for transport, floating, etc., is 1.62 per tree. For fuel the costs are much higher, depending on the distance the wood has to be transported to the consumer. If this distance is only 3–4 km. the total production is 2.43 per tree, leaving a net margin of 0.89 öre; if the distance is 5–7 km. the net dwindles to 0.23 öre.

If we further assume that the number of trees per hectare is 450 and that 33 per cent. of these are killed, the total loss per hectare, if through the agency of the insects the quality of the logs is reduced from unassorted to V, amounts to 211.50 Sw. crowns. If, on the other hand, the trees die and are attacked by the pine sawyer to such a great extent that logging becomes impossible, they must be cut up for fuel. In this instance the loss is equal to $3.55 - 0.89 = 2.66$ per tree or 400 Sw. crowns per hectare, if the distance to the consumer is 3–4 km. but 3.32, or 498 Sw. crowns per hectare, if the distance is greater. The loss is therefore, even at a conservative estimate, equal to at least 200 Sw. crowns per hectare and may be considerably greater.

When the effect of a defoliation is only a decrease in the growth, this loss may be measured and estimated in cubic metres. If this decrease is so marked that the result is a loss of 10 cu. m. per hectare, it is equal to a loss of at least 36.50 Sw. crowns per hectare, if we assume that the trees are cut up for timber.

It finally remains to calculate the cost of aeroplane dusting. We assume that the Russian method is adopted, *viz.* that calcium arsenite is used without any admixture of inert substances and the dusting is carried out when the larvae are still young, so that 10 kg. per hectare is sufficient. We further assume that 8 trips are made each day, which is less than in Russia, although the length of the day is far greater in Sweden during the summer than in Ukraine, where the Russian dusting operations were carried out.

Further we assume that each trip requires one hour including the loading, the ascending and descending, and that the aeroplane carries 250 kg. of dust and uses 10 kg. per hectare. In this way it is possible to treat 200 hectares each day. Assuming that the cost of flying is 150 Sw. crowns an hour, which is an unduly high amount, since the actual period of flying during each trip is probably not half an hour, the cost of dusting is $150 \times 8 : 200 = 6$ Sw. crowns per hectare. For the dusting of 200 hectares 2 tons are necessary, which costs 1,000 Sw. crowns or 5 Sw. crowns per hectare. If we further add 9 Sw. crowns per hectare for all other expenses, in order to be on the safe side, we arrive at a total of 20 Sw. crowns per hectare.

This sum is fortunately much lower than the price given by the German forest entomologists, *viz.* 50 goldmarks or 75 Sw. crowns per hectare. It makes aeroplane dusting against forest insects a very remunerative investment, even if the economic loss caused by them is of a magnitude of about 200 Sw. crowns per hectare, which is a fairly common occurrence in Sweden, *e.g.* after defoliation by the pine-looper. Thus aeroplane dusting seems to be a fairly safe venture, even when the injury is restricted to a decrease in the growth.

HEMIPTEROUS PREDATORS OF THE WEEVILS *COSMOPOLITES* AND *ODOIPORUS*.

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This paper is based on material submitted for identification by the Imperial Institute of Entomology and received from Mr. G. H. Corbett, Government Entomologist of the Federated Malay States.

Family CYDNIDAE.

***Geotomus pygmaeus*, Dall.**

Aethus pygmaeus, Dall., List Hemipt. Brit. Mus. i, p. 120, 1851.

Geotomus pygmaeus (Dall.) China, Ins. Samoa, ii, fasc. 3, p. 89, 1930.

Reported by Corbett as predacious on the eggs of the weevils. This species has been described under no less than ten names (see second paper quoted), although it is by no means certain whether this synonymy is correct. *G. pygmaeus*, Dall., is recorded from India, Burma, Ceylon, Java, Sumatra, Borneo, Cochin-China, China, Japan, New Caledonia, Fiji, Samoa, Tahiti, Raiatea and Hawaii. Its extensive distribution has been attributed by Kirkaldy to the fact that it is readily introduced to new localities in the soil attached to the roots of cultivated plants transported by man.

All the members of the CYDNIDAE so far as is known live and breed below the surface of the soil and feed on the roots of plants, although the adults may often be found on the surface of the ground. The structure of the rostrum is not adapted to predacious habits and it therefore seems unlikely that this species is normally a predator.

Family REDUVIIDAE.

***Physoderes curculionis*, sp. nov.**

♂. Head about as long as pronotum in middle (38), insertion of antennae nearer eyes than apex of head (7 : 10), first segment barely reaching apex of head. Relative lengths of antennal segments :—17 : 22 : 18 : 20. Anterior lobe of pronotum distinctly longer than posterior lobe (21 : 17) and only slightly narrower (53 : 56), not or very slightly raised above level of posterior lobe, without tubercles or spines but with short bristly pubescence laterally : tongue-shaped posterior lobes on each side of scutellum slightly shorter than broad, outwardly straight inwardly rounded ; posterior lateral margins of pronotum feebly emarginate. Scutellum relatively broad at apex. Front femora with two rows of spines, inner with two to three large spines, outer with three small spines and intermediate setigerous tubercles. General colour dirty greyish black, head below and in front of antennal tubercles, rostrum except apical segment, base and apex of first antennal segment, and lateral margin of posterior lobe of pronotum, fulvous or yellowish fulvous ; an irregular spot in middle of base of pronotum, scutellum and a band across base of each connexival segment, yellow ; posterior process of pronotum sordid yellow. Hemelytra black, somewhat greyish towards base. Legs pale fulvous, a broad brown basal annulation and a narrower brown apical annulation on femora ; a sub-basal brown annulation and an apical brown annulation on tibiae. Underside blackish brown with acetabulae and an obscure spot in middle of metapleuron sordid yellow ; an obscure fulvous

lateral longitudinal stripe down each side of venter, a broader orange stripe along inner margin of connexivum covering spiracles and a yellow band across base of each connexival segment.

Length 7.8 mm., width across humeral angles 2.6 mm.

MALAY PENINSULA: Serdang. 1 ♂ & 1 ♀, "predacious on *Cosmopolites* and *Odoiporus* grubs," 14.i.1935 (G. H. Corbett).

Closely allied to *P. fuscus*, Bredd. (Tonkin) but differs in the broader anterior lobe of pronotum, nearly as wide as posterior lobe, with the lateral margins without teeth-like tubercles.

The genus *Physoderes* was described by Westwood in Proc. Ent. Soc. London, 1845, p. 115 (not Ann. Mag. Nat. Hist. xvii, p. 67, 1846, as stated by Sherborn). In Trans. Ent. Soc. London iv (14), March 1847, p. 247, Westwood illegally renamed his genus *Epirodera* to prevent confusion with the genus *Physodera*, Eschsch. 1829 (Col.). In this he was followed by Distant. Breddin used the original name in 1903, when he described four new species of the genus (S. B. Ges. naturf. Freunde, no. 3, pp. 125-128, 1903), but mis-spelt the name *Polyderus*. Distant wrongly synonymised *P. fuscus*, Bredd., under his *P. impexa* (Burma). In spite of Breddin's comment, this species is distinct from *P. impexa*, Dist., in the structure of the pronotum. *P. curculionis* differs from *P. impexa* in the much broader apical lobe of the scutellum.

Family NABIDAE.

Phorticus pygmaeus, Popp.

Acta Soc. Sci. Fenn. xxxvii, no. 2, p. 56, 1909.

MALAY PENINSULA: Kuala Lumpur, ♂, 1 ♀ (immature), 18.i.1935, 1 ♀ & 1 larva, 25.i.1935, "preying on *Cosmopolites* and *Odoiporus* eggs."

These specimens, all of which are macropterous forms, seem to represent one species the difference in colouring being due to specimens being killed at various stages of maturity apart from a certain amount of variation. The fully mature specimen (25.i.1935) strongly resembles *P. cingalensis*, Dist., but is a much smaller insect with the anterior collar of pronotum not entirely yellow. The sub-mature specimen agrees very well with Poppius' description of *P. pygmaeus*, which may have been described from immature specimens. The completely teneral specimen has the fuscous markings greatly reduced, the pronotum being entirely ochraceous. More mature material is necessary before coming to a definite conclusion. *P. pygmaeus* was described from New Guinea.

Family CAPSIDAE.

Fulvius nigricornis, Popp.

Acta Soc. Sci. Fenn. xxxvii, no. 4, p. 37, 1909.

MALAY PENINSULA: Khumpur, 1 ♂ & 1 ♀, 1.ii.1935, "preying on *Cosmopolites* and *Odoiporus* eggs."

Recorded by Poppius from the Mentawai Islands.

PHASE VARIATION IN NON-SWARMING GRASSHOPPERS.

By I. A. RUBTZOV.

(PLATES XIX & XX.)

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Introduction.

The theory of phase variation in swarming locusts, which was proposed by Uvarov in 1921, further developed by him in 1928, and supplemented by the extensive experimental work of Faure (1932) and field observations of Zolotarevsky (1933), has now been accepted by practically all entomologists. There is no need to repeat the basic principles of the theory, but it may not be out of place to mention some of the criticisms directed against it.

Curiously enough, the greatest amount of experimental work intended to discredit the phase variability in locusts has been carried out by Plotnikov (1923, 1924, 1927), who was the first to observe the phase transformation in a laboratory (1915) and point out the importance of the density factor in the transformation. As a result of his experimental work on *Locusta migratoria migratoria*, L., Plotnikov (1927) concluded that the forms designated as the solitary and the gregarious phases of that species are hereditary, fixed independent races, which are able to produce hybrids and are subject to strong individual variation under the influence of external conditions. These variations follow the law of homologous series (Vavilov, 1922), and the variations of the two races overlap to the extent of creating a false impression of a gradual transition from one to another (as it should be in the case of phases). Referring to the law of homologous series, Plotnikov says that "if we give a different explanation to the existence of parallel forms in ACRIDIDAE, we must reject that law."

However, as we shall see later, the acceptance of the phase variation by no means requires the rejection of Vavilov's law.

Objections similar to those of Plotnikov were raised by Potgieter (1929), but Faure (1932) disposed of them in a very convincing manner.

Makalovskaya (1925, 1926) was unable to find any proof of the phase transformation in the specimens of the Migratory locusts which she has studied. Alpatov (1927), however, proved that this was due to the incorrect treatment of the biometrical data.

Olsuf'ev (1930) objected to the statements that the phase variation is a factor affecting mass outbreaks of locusts. It must be remembered, in this connection, that Uvarov himself (1928) considered climatic factors as the primary cause in the increase of locust populations. Subsequent work by Zolotarevsky (1933) supplied excellent field data on the origin of locust outbreaks as caused by local climatic variations and the ability of locusts to pass from one phase to another.

As the result of the various criticisms just reviewed, Uvarov's phase theory became only more firmly established. Until now, however, the theory has been considered applicable to the typically gregarious locusts only, and all the authors presumed that phase variation does not occur in the non-swarming grasshoppers. Special experiments made by Faure (1932) on crowding and isolating non-gregarious grasshoppers (*Oedaleus nigrofasciatus*, DeGeer, and *Acanthacris ruficornis*, F.) produced negative results. The crowded hoppers did not exhibit any increase in activity and did not differ in the coloration from the isolated ones. Faure, who is the best authority on the experimental side of the problem, regarded phase variation as a special character of the swarming ACRIDIDAE.

However, one can find in the literature (Skalozubov, 1893, 1895; Nosov, 1895; Uvarov, 1928; Criddle, 1933) some indications that certain non-gregarious grasshoppers, during mass multiplication, behave in a manner resembling that of the gregarious species, for they form bands and even undertake swarm flights. Moreover, Plotnikov (1926) observed that the hoppers of such a typically non-gregarious species as *Aiolopus tergestinus*, Charp., when bred under crowded conditions, develop a much darker coloration than usual.

I have had an opportunity to study the colour variations in a number of non-gregarious species in Siberia, and was struck by the analogy of the variations to those observed between the phases of gregarious locusts. Particularly interesting is the fact that the extent of the variation is greater in the species which are most active and which may form dense populations. Thus, the greatest extent of colour variation analogous to that in the gregarious species is observed in *Aeropus sibiricus*, L., a very active species, which during mass outbreaks has been occasionally observed to fly in swarms. Under certain conditions the second and third stage hoppers may reach the densities of 200-300 individuals per square metre. The next in order is *Chorthippus albomarginatus*, DeG., which also breeds in dense accumulations and is no less active; its colour variation is equally extensive, but the colours are less striking. The following species can also be mentioned in the descending order of the tendency to form aggregations and of the colour variations: *Chorthippus biguttulus*, L., *Omocestus haemorrhoidalis*, Charp., *Chorthippus apricarius*, L., and *Arcyptera microptera microptera*, F. W. While all these species may occur in bands, this tendency is very feebly expressed in others, such as *Stauroderus scalaris*, F. W., *Myrmeleotettix palpalis*, Zub., and *Stenobothrus nigromaculatus*, H. Sch. These never form populations denser than 50 and usually not more than 10 per square metre. In their colour variations the same tendencies are also exhibited, but in a very slight degree.

The remaining 40 species of grasshoppers studied by me occur as a rule in populations not exceeding one individual per square metre, and their coloration is much more constant. When large series of hoppers and adults of these species are studied, they also prove to be variable in colour, but the variations are of a different kind,

viz. they are the hereditary ones belonging to the homologous series, and the individual adaptive variations, such as the imitating of the colours of the environment. Variations of the latter type are more extensive in the species subject to a greater variety of environments. For example, *Chorthippus fallax*, Zub., inhabiting many very different stations and appearing in the adult stage very late in the season when the vegetation assumes various bright autumn tints, has a great range of colour variation, some individuals being uniformly green, others purple, brown, mottled, etc. *Bryodema tuberculatum*, L., which lives on bare ground, imitates the colour of the soil. *Mecostethus grossus*, L., living in swamps has in its coloration olive-green, purple, yellow-green and reddish tints harmonising with the environment. However, in all these typically solitary grasshoppers the coloration is relatively stable within a certain type, and in them there is never observed that combination of black pattern with the pale brownish-grey or yellowish ground, which is so characteristic of *Aeropus sibiricus*, *Chorthippus albomarginatus* and *C. biguttulus*. In these latter species, side by side with the adaptive types of coloration, there is a striking combination of black and yellow colours, and the black colour is more pronounced when the hopper population is more dense. On the other hand, when the population is sparse light green and green colours predominate.

These field observations suggest that here there is not merely an analogy with the gregarious species, but that the phenomena are essentially the same. Consequently, it can be expected that the non-swarming species will exhibit the whole range of morphological and biological differences characteristic of phases. However, the amplitude of these differences in our grasshoppers should be considerably less than in locusts. Accordingly, great care must be observed in the interpretation of data, and special stress must be laid on the exact measurements, statistical evaluation of the results, and on the experimental reproduction of the observed phenomena. The biometrical work in this case is made still more difficult by the small extent of variations in the size of the measured parts. Uvarov's (1928) statement that the biometric method can be reliable only if it is applied to a material with strictly defined biological characteristics is particularly true in our case. Still further complications are introduced by the presence of hereditary variations in homologous series, which may interfere with the phase variations and even obscure them. In order to avoid this, it is absolutely essential to separate the two types of variations, and therefore the hereditary homologous variations must be studied before we can proceed to discuss the phase variation.

The observations and experiments on which the present work is based were made during the summer of 1934 with the assistance of G. R. Arens and A. A. Gontcharova, who have done most of the measurements and calculations. The illustrations are by the author. The text has been translated from the Russian manuscript by Mr. B. P. Uvarov, to whom my thanks are due both for this and for assistance in the publication of the paper.

Material and Methods.

All the observations on the colour variation of *Chorthippus albomarginatus* have been made on live material, mostly bred in the laboratory, but partly collected in the field. Collections were made mainly in three stations, 200–300 metres distant from each other, but differing greatly as regards the density of population of *Ch. albomarginatus*. The first station was a badly overgrazed pasture covered with nettles (*Urtica cannabina*), *Agropyrum repens* and *Poa angustifolia*. The hoppers were breeding here under crowded conditions, the density of their population, shortly after the emergence, reaching 150–200 per square metre. In the second station, with a mixed cover of grasses including the above species, *Carex stenophylla* and broad-leaved plants, the density was everywhere less than 1 per sq. m., *i.e.* the hoppers bred as solitaries. In the third station, on a pasture of mixed plants and

grasses, the density was from 5 to 20 individuals per sq. m., that is intermediate conditions were realised. In all the three stations regular observations were made on the varietal composition of the population, and on the changes in that composition due to migrations and to the growth of the insects.

Special attention was paid to the breeding of hoppers in crowded and solitary conditions, according to Faure's method (1932). For the solitary hoppers we used cylindrical cages 12 cm. in diameter and 20 cm. high, made of dark wire netting. For the same purpose, gauze cages, 10–12 cm. in diameter and 15 cm. high, were used to cover the grass, or to be tied up on plants at some distance above the ground.

For crowding the hoppers the same kind of wire netting cages were used, as well as larger square ones, measuring $16 \times 20 \times 24$ cm., with wooden frames and wire netting walls. Food was given once a day, in the morning, and a thin layer of turf was placed at the bottom.

Hoppers for cage experiments were mostly bred in the laboratory from egg-pods collected in the station with a dense population, but later in the season hoppers mostly of younger stages were collected in the field. The experiments commenced in the middle of May, and cold rainy weather caused a very high mortality in the cages, interfering with the successful completion of some experiments.

For the biometric measurements at first we used Faure's method of taking the length of the femur and the elytron by compasses and applying the ends of the latter to a ruler. This method is liable to cause errors up to 0.1 mm. in both directions, which was unacceptable since we had to deal with differences not exceeding 0.5–1.0 mm. We have, therefore, increased the exactitude of our measurements by taking them under binoculars with a 20-fold magnification. An elytron, or a femur, was detached and placed on a ruler divided to 0.1 mm. This made the measurements exact to ± 0.025 mm. The length of the elytron was measured from the apex of the tubercle at the base of the radial veins to the apex of the elytron.

Homologous Series of Variations in Grasshoppers.

According to the now accepted view a Linnean species (a linneon) represents a mobile and complicated system of forms. A comprehensive expression of this idea was first given in the law of homologous series by Vavilov (1922), as follows:—Linneons and genera more or less nearly related to each other are characterized by similar series of variation with such a regularity that, knowing a succession of varieties in one genus and linneon, one can forecast the existence of similar forms and even similar genotypical differences in other genera and linneons. The similarity is the more complete as the linneons and genera are more nearly allied.

The truth of this law has been repeatedly demonstrated, not only in plants but in animals as well, and the law holds good not only for morphological and physiological characters but also for biological ones. We shall study these groups of characters in our case one by one.

Colour Variation.

So far as I know, the first attempt to analyse the homologous colour variations in ACRIDIDAE was made by Vorontsovsky (1927). This author proved that Vavilov's law is applicable to the series of variations in 48 species of ACRIDIDAE, and established over 20 types of coloration. As is to be expected, the closely related species are characterised by the greatest similarity in the series of colour variations. Thus, *Chorthippus parallelus*, Zett., and *C. albomarginatus* have six homologous colour types. It is of interest that from the table of homologous variations given by Vorontsovsky, one can see that the number of homologies is greater in those species for which the investigated area (Orenburg district) is near to the centres of their

mass outbreaks. Thus, in the case of *C. parallelus*, the approximate centre of whose outbreak area is at Orenburg, as many as 38 cases of homologous colour types have been observed in other species. For *Acrydium bipunctatum*, L., which at Orenburg is near the periphery of its distribution area, only two homologies are recorded. On the other hand, in Eastern Siberia, which is more on the periphery of the distribution area of *C. parallelus* and near the centre of the area of *A. bipunctatum*, the number of homologies is not more than 2-3 in the first named species, and some scores in the second. This fact also suggests that Vavilov's law of homologous variations is fully applicable to colour variability in grasshoppers.

In *Chorthippus albomarginatus*, of which I made a special study, six distinct colour types have been observed within the area investigated by us. They are designated by the names given to them by Vorontsovsky (*l. c.*), as follows:—

1. *f. viridis*.—Green all over (except the ventral surface), with more or less distinct ochreous or brownish-black shading on the antennae, compound eyes, legs and abdomen (Plate XX, fig. 20).

2. *f. hyalosuperficies*.—The following parts are green above: head, pronotum between the carinae, elytra (behind the first ulnar vein). Sides of the body and legs vary from ochreous brown to brownish black (Plate XX, figs. 16, 17).

3. *f. hyalolateralis*.—The following parts are green laterally: head, sides of thorax, legs and abdomen (the latter sometimes covered with brownish-black spots). Dorsal surface most frequently ochreous brown (Plate XX, figs. 18, 19).

4. *f. rubiginosa*.—Brown all over, with more or less distinct black markings near the pronotal carinae and on the sides of the abdomen. General colour varies from light brown to blackish brown.

5. *f. porphyrica*.—Purple above (head, pronotum between carinae, elytra); green laterally; abdomen and legs with ochreous brown and brown spots (Plate XX, figs. 22, 23).

6. *f. fuliginosa*.—Blackish brown above (top and sides of the head; disc of pronotum and its lateral lobes in their upper halves; the whole of elytra; abdomen above and on the sides). Cheeks and lower halves of the lateral pronotal lobes yellowish white.

Apart from the above six types, there occur other forms, such as green laterally with the dorsum ochreous (Plate XX, fig. 25), or coloured as *f. fuliginosa* laterally, but like *f. hyalosuperficies* dorsally, etc. They may be the results of hybridisation.

We had in our possession a mass of material of the first four races, which were studied experimentally and biometrically, as well as with regard to their bionomics. Hence, only these four types (*viridis*, *hyalosuperficies*, *hyalolateralis* and *rubiginosa*) will be thoroughly discussed.

The four types of coloration can be observed already in the first stage hoppers, and are quite definitely developed in the second stage, both in the field and in cages. Our experiments (over one hundred in number) with breeding differently coloured hoppers in cages showed that there was no change in the type of coloration, regardless of whether the hoppers were bred under crowded conditions or singly in cages painted whitish, green, yellow or black. It is true that there were some changes in the extent of black spots and other less important details, but these belong obviously to another category of variability, namely that connected with phases, and will be discussed later. The type of coloration characterised by the relative extent and distribution of the green and brown colour was never changed. Green hoppers, during their individual life, cannot be changed into brown ones, or *vice versa*, either by crowding or isolation, or by the influence of high or low humidity. These facts are particularly interesting in view of Faure's (1932) experiments on *Locustana pardalina*, Walk., in which species the green colour proved to be dependent on high humidity and abundant green food.

However, as we shall see later, green forms of our grasshoppers are in some respects analogous to the similar forms in *Locustana*. They occur mainly in humid habitats, and their percentage in the population increases with the humidity of the habitats. However, it is impossible to decide without special breeding experiments whether this is due to a gradual change under the influence of environmental conditions during a series of generations, or to a segregation of hereditary factors following Mendel's law. The experiments in hybridising the forms with different types of coloration, as well as with breeding them under different conditions, are in progress, and the results will be published later. At present, we are inclined to believe that the types of coloration are hereditary.

In order to obtain an idea whether the series of colour variations are constant in other ACRIDIDAE, we studied the large materials of the Zoological Institute of the Academy of Sciences (Leningrad), our own collections made during many years, as well as the data published by Vorontsovsky (*l. c.*). We studied, first of all, a number of species of the genus *Chorthippus*, then some species of closely allied genera, such as *Omocestus*, *Myrmeleotettix*, *Gomphocerus*, *Aeropus*, *Dasyhippus* and *Aiolopus*. The results are represented in Table I.

TABLE I.
Homologous Colour Forms in some Grasshoppers.

Species	Forms					
	<i>viridis</i>	<i>hyalo-lateralis</i>	<i>hyalo-superficies</i>	<i>rubiginosa</i>	<i>purpurata</i>	<i>fuliginosa</i>
<i>Chorthippus albomarginatus</i> , DeG. ...	+	+	+	+	+	+
„ <i>dorsatus</i> , Zett. ...	+	+	+	+	+	+
„ <i>biguttulus</i> , L. ...	+	+	+	+	+	+
„ <i>parallelus</i> , Zett. ...	+	+	+	+	+	+
„ <i>macrocerus</i> , F. W. ...	+	+	+	+	—	—
„ <i>vagans</i> , Eversm. ...	+	—	—	+	+	—
„ <i>bicolor</i> , Charp. ...	+	+	+	+	+	+
„ <i>miramae</i> , Ramme ...	+	—	+	+	+	+
„ <i>fallax</i> , Zub. ...	+	+	+	+	+	—
„ <i>mollis</i> , Charp. ...	+	+	+	+	—	—
„ <i>longicornis</i> , Latr. ...	+	+	—	+	+	—
„ <i>apricarius</i> , L. ...	+	+	+	+	—	+
„ <i>scalaris</i> , F. W. ...	+	+	—	+	—	—
<i>Omocestus viridulus</i> , L. ...	+	+	+	+	+	—
„ <i>haemorrhoidalis</i> , Charp. ...	—	—	+	+	—	—
„ <i>petraeus</i> , Bris. ...	—	+	—	+	—	—
„ <i>panteli</i> , Bol. ...	+	—	—	+	—	—
<i>Myrmeleotettix maculatus</i> , Thunb. ...	+	—	+	+	—	—
„ <i>palpalis</i> , Zub. ...	+	—	—	+	—	—
<i>Gomphocerus rufus</i> , L. ...	+	+	+	+	—	—
<i>Dasyhippus variegatus</i> , F. W. ...	—	+	—	+	—	—
<i>Aeropus sibiricus</i> , L.	+	+	—	+	—	—
<i>Stenobothrus nigromaculatus</i> , H. Sch. ...	+	+	—	+	—	—
„ <i>eurasius</i> , Zub. ...	+	+	—	+	—	—
„ <i>lineatus</i> , Panz.	+	+	—	+	+	—
<i>Aiolopus tergestinus</i> , Fisch. ...	+	+	—	+	+	—
	23	20	14	26	12	7

+ means that the corresponding colour form is known in the species.

— means that the form is not yet known.

As will be seen from the table, the first four races, *viridis*, *hyalolateralis*, *hyalosuperficies* and *rubiginosa*, occur in practically all the examined species belonging

to eight genera. It is almost certain that the incompleteness of a series, at least for the species of *Chorthippus*, results only from insufficient material, and the lacking homologous forms will probably be found in all the species. Even now, there is no doubt that Vavilov's law is fully applicable to the group of genera which we have studied.

Morphological Variation.

The question arises now, whether the homologous forms, which are so strikingly different in colour, differ also morphologically and biologically.

The absence of references in systematic papers to morphological differences between various colour forms suggests that these differences, if they exist, are small. They must, therefore, be studied very carefully and in the material collected at one place and at the same time. Exact methods of variation statistics should be applied in order to avoid statistical errors.

For the biometrical characteristics of the races we have taken three most reliable figures, *viz.* the length of the hind femur (F), the length of the elytron (E), and their ratio (E/F). The insects to be measured were collected by sweeping in one habitat, classified by colour types, and then measured under binoculars as described above (see page 502). The two sexes were measured and will be discussed separately, beginning with females, which show the differences more clearly (Table II).

TABLE II.

Biometrics of the Females of Four Colour Races in Chorthippus albomarginatus.

No. of specimens	Min.	Max.	Mean	σ	m.
Femur (F.)					
1. <i>rubiginosa</i> ... 216	9.0	11.9	10.0	0.90	0.06
2. <i>hyalosuperficies</i> ... 69	9.5	11.9	10.5	0.50	0.06
3. <i>hyalolateralis</i> ... 111	9.0	11.9	10.5	0.51	0.05
4. <i>viridis</i> ... 34	9.6	11.7	10.6	0.42	0.07
Elytron (E.)					
5. <i>rubiginosa</i> ... 216	10.3	15.6	13.6	0.95	0.06
6. <i>hyalosuperficies</i> ... 69	11.0	15.6	13.8	0.96	0.12
7. <i>hyalolateralis</i> ... 111	12.0	15.4	13.8	0.71	0.07
8. <i>viridis</i> ... 34	12.0	15.6	14.0	0.86	0.14
Ratio E/F.					
9. <i>rubiginosa</i> ... 216	1.45	1.11	1.35	0.078	0.006
10. <i>hyalosuperficies</i> ... 69	1.47	1.11	1.32	0.087	0.009
11. <i>hyalolateralis</i> ... 114	1.47	1.11	1.32	0.070	0.002
12. <i>viridis</i> ... 34	1.43	1.18	1.32	0.076	0.013

It will be seen from the table that the four most common colour races have substantial biometrical differences. Thus, f. *viridis* is, on the average, the largest of all. The differences between f. *rubiginosa* and f. *viridis* are particularly noticeable,

while *f. hyalosuperficies* and *f. hyalolateralis* take a position intermediate between the first two and are very close to each other. The index E/F in *f. viridis* is smaller, which means that an increase in size is accompanied by a relative shortening of the elytra. *F. rubiginosa* is the smallest and has relatively the longest elytra.

That these differences are real, can be shown by the formula :—

$$R = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}}$$

which equals 6.5 when the lines 1 and 4 of Table II are tested ; for the lines 5 and 8 it is 2.7 ; and for the lines 9 and 12, it is 20.0.

It can be seen without special calculations that the two intermediate forms (*hyalosuperficies* and *hyalolateralis*), while not differing from each other in size, are significantly different from the other two.

TABLE III.

Biometrics of the Males of Four Colour Races in Chorthippus albomarginatus.

No. of Specimens				Min.	Max.	Mean	σ	m.
Femur (F.)								
1.	<i>rubiginosa</i>	...	104	7.9	9.3	8.64	0.34	0.033
2.	<i>hyalosuperficies</i>	...	38	8.0	9.9	8.73	0.46	0.07
3.	<i>hyalolateralis</i>	...	87	8.0	10.0	9.0	0.41	0.04
4.	<i>viridis</i>	...	35	8.3	10.0	9.2	0.40	0.07
Elytron (E.)								
5.	<i>rubiginosa</i>	...	104	10.2	13.2	11.7	0.61	0.06
6.	<i>hyalosuperficies</i>	...	38	10.6	13.3	11.8	0.62	0.01
7.	<i>hyalolateralis</i>	...	87	10.8	13.6	12.0	0.50	0.05
8.	<i>viridis</i>	...	35	11.0	13.4	12.3	0.62	0.01
Ratio E/F.								
9.	<i>rubiginosa</i>	...	104	1.62	1.14	1.36	0.072	0.007
10.	<i>hyalosuperficies</i>	...	38	1.64	1.13	1.35	0.085	0.007
11.	<i>hyalolateralis</i>	...	87	1.54	1.22	1.34	0.063	0.007
12.	<i>viridis</i>	...	35	1.59	1.28	1.34	0.069	0.011

It is particularly interesting to note that the amplitude of fluctuations in the length of femur, elytron, and in their ratio (as well as in other characters, as will be shown later) is greatest in *f. rubiginosa*, smallest in *f. viridis*, and of medium value in the two intermediate forms. This can be seen from the value of α as well as from the difference between the minimum and the maximum (see Table II).

The greater morphological variability of *f. rubiginosa* is accompanied by its greater colour variability as compared with *f. viridis*. This fact is correlated with their respective habitats, as will be seen later.

In the case of males (Table III), the biometrical differences between colour races are of the same kind as in the females (see above). That the differences are significant, can be seen from the value of *R*, which for the lines 1 and 4 equals 7.5; for 5 and 8 it is 9.5; for 9 and 12, 8.0; for 1 and 3, 7.0; for 1 and 2, 1.2; for 5 and 6, 1.7; for 3 and 4, 2.5; and for 7 and 8, 6.0.

An examination of specimens of *Chorthippus albomarginatus* collected in other areas of Eastern Siberia and at other times confirmed the differences, as can be seen from Table IV.

TABLE IV.

Biometrics of Two Colour Races of Chorthippus albomarginatus collected in different Areas of Eastern Siberia.

		Kharki, Kuitunsk Distr., 1933				Molka, Balagansk Distr., 1931			
		♂ ♂		♀ ♀		♂ ♂		♀ ♀	
		No. of spec.	Mean	No. of spec.	Mean	No. of spec.	Mean	No. of spec.	Mean
<i>rubiginosa</i>	F	50	8.5	50	10.9	20	8.7	24	11.0
	E		11.8		14.2		11.9		14.3
	E/F		1.39		1.3		1.37		1.3
<i>viridis</i>	F	30	8.9	16	11.2	14	8.8	17	11.2
	E		11.8		14.2		11.9		14.4
	E/F		1.33		1.29		1.35		1.29

It appears that similar interrelations between colour forms exist in other species of grasshoppers, which have been studied in a preliminary way (see Table V).

TABLE V.

Biometrics of Colour Races in different Species of Grasshoppers.

		<i>Chorthippus dorsatus</i>				<i>Chorthippus scalaris</i>				<i>Aeropus sibiricus</i> Balagansk Distr. 1928			
		No. of spec.	Mean	No. of spec.	Mean	No. of spec.	Mean	No. of spec.	Mean	No. of spec.	Mean	No. of spec.	Mean
<i>rubiginosa</i>	F	13	9.0	18	11.9	17	11.6	25	13.4	50	11.1	50	11.9
	E		11.76		14.1		17.8		17.6		14.5		14.2
	E/F		1.32		1.19		1.54		1.32		1.32		1.21
<i>viridis</i>	F	7	10.1	9	13.0	12		21		50	11.2	50	12.1
	E		13.3		15.4						14.7		14.3
	E/F		1.32		1.19						1.32		1.18
<i>hyalo-lateralis</i>	F						11.8		13.4				
	E						18.0		17.6				
	E/F						1.54		1.32				

The index E/F is approximately the same in all cases, but the absolute length of both femur and elytron is greater in *f. viridis*, which is a larger race. It is of interest that the "danicoids" of *Locusta*, which Plotnikov (1924) regarded as a race, were also larger and of less frequent occurrence than the others.

Differences in Habitat and Abundance.

The differences between *f. viridis* and *f. rubiginosa* are particularly striking in regard to their optimal habitats and relative abundance. The individuals of *f. viridis* prefer more humid and stable mesophytic habitats, and as a rule they are always less abundant than those of *f. rubiginosa*. The latter occur in more xerophytic and less stable habitats (pastures), and in all the observed cases of mass multiplication of *Chorthippus albomarginatus* the brown *f. rubiginosa* definitely predominated. An example is given in Table VI.

TABLE VI.

Percentage of different Colour Races in the Populations of different Habitats in the Balagansk Steppe in 1932.

Habitats	Percentage in the population				Average number of individuals per 1 sq. m.	Number of specimens studied
	<i>rubi-ginosa</i>	<i>hyalo-superficies</i>	<i>hyalo-lateralis</i>	<i>viridis</i>		
1. Margin of forest ; humid ; dense vegetation	37.3	24.6	23.9	14.2	Less than one	198
2. One kilometre from the forest ; more dry ; rich vegetation	48.0	12.0	34.0	6.0	About one	232
3. Twenty km. from the forest, near river ; close to the next habitat	59.0	12.5	23.0	5.5	10-20	164
4. Ditto ; a dry habitat ...	65.2	14.1	18.5	2.2	25-50	780
5. Ditto ; the driest habitat	71.4	10.3	16.2	2.1	50-150	850

The table shows that *f. rubiginosa* predominates in all the habitats, but in the humid and rich ones it forms less than 50 per cent. of the population, while in the xerophytic habitats its relative abundance is much greater. Exactly the reverse is true for *f. viridis*, and the increase of one form and the decrease of the other are clearly parallel with the increasing dryness of the habitats. The two other races again occupy an intermediate position.

Similar observations have been made on populations of *Chorthippus albomarginatus* during a series of years in different areas of Eastern Siberia, and the green mesophilous *f. viridis* was always less abundant as compared with the more xerophilous brown *f. rubiginosa*. Some observations on the populations of *Aeropus sibiricus*, *Stauroderus moris* and *Omocestus haemorrhoidalis*, suggest analogous relations between different forms in these species as well.

Differences in Behaviour.

Very significant differences between *f. viridis* and *f. rubiginosa* can be observed when migrations of these forms are studied.

Our observations on migrations of grasshoppers made during a series of years indicated a greater extent of migrations in brown forms (*f. rubiginosa*) than in others bred under the same environmental conditions. When aggregations of third stage hoppers in small depressions on the ground were observed, the percentage of brown forms in them was greater than in the surrounding habitat whence these hoppers migrated to the depressions. Towards the autumn, when the grasshoppers, as a rule, begin to disperse from densely populated areas, the percentage of green forms in the latter increases, while in the adjoining areas, with sparse populations, a reverse process is observed. This demonstrates the greater mobility of the brown forms (*f. rubiginosa*). In 1934 regular observations were organised throughout the summer. The plot taken

for these studies represented about half a hectare of dry pasture, entirely flat, slightly sloping towards the south-west. The vegetation was sparse and consisted of *Poa pratensis*, *Festuca ovina*, *Artemisia scoparia*, *A. vulgaris*, etc. The grasshopper population consisted almost entirely (99 per cent.) of *Chorthippus albomarginatus*, and the density of the population soon after the completion of hatching fluctuated from 100 to 150 individuals to one square metre. A little lower down the slope, where the vegetation was somewhat denser, with *Carex stenophylla* and *Festuca ovina* predominating, the density was from 5 to 10 per square metre. The grasshoppers were collected by sweeping about once every ten days in the densely populated habitat and the percentage of green and brown forms was counted. The results were further checked several times by covering small plots with a square net and counting the percentage of the forms under the net. The results are presented in Table VII.

TABLE VII.

Variation in the Percentage of different Colour Forms on a Sample Plot throughout a Season.

	17.vi.	25.vi.	7.vii.	17.vii.	27.vii.	3.viii.
<i>rubiginosa</i>	78.2	76.2	69.9	67.3	56.5	54.9
<i>hyalosuperficies</i>	7.3	7.4	10.6	10.8	11.0	12.4
<i>hyalolateralis</i>	13.7	14.4	16.4	15.0	22.2	20.2
<i>viridis</i>	1.8	2.0	3.1	6.9	10.3	12.5
Average density per sq. metre	150-200	100-150	50-70	30-40	20-25	10-12

The gradual general decrease in the population is due partly to mortality from various causes, but mainly to the dispersal of hoppers and adults in various directions. The reduction in the percentage of the brown forms is particularly rapid, and their absolute number per unit of area decreases to one-tenth or one-fifteenth of the original population. The absolute number of the green forms per unit of area also decreases to about one-half, but their percentage in the population towards the end of the year increases from 2 to 10-15 per cent.

These seasonal changes in the population should be explained by the greater mobility of the brown forms and by the inactivity of the green ones. Further proofs of this will be given below.

Summary.

1. In *Chorthippus albomarginatus* a series of colour forms can be distinguished, and the same series is found in other species closely related to them, while in the species removed from them systematically only some of these forms are observed.

2. These types of coloration do not change during the individual life, even if the environmental conditions (food, density of population, temperature, humidity, etc.) are changed.

3. The colour forms differ in their dimensions, particularly in the length of hind femur and elytron, and in their ratio. Green forms (f. *viridis*) are larger than the brown ones (f. *rubiginosa*).

4. Green and brown forms differ in their habitat preferences, the green ones being more mesophilous.

5. In Eastern Siberia mainly the brown forms appear in masses, while the green ones, as a rule, appear singly.

6. The behaviour of the two forms is different, the brown ones appearing in masses, being more mobile and inclined to migrations.

7. Analogous phenomena are observed in the field in other species (*Aeropus sibiricus*, *Chorthippus biguttulus*, *C. parallelus*, etc.).

6. These groups of phenomena comply fully with the requirements of Vavilov's law of homologous series, and our colour forms can be regarded as races.

Phase Variation.

Since the variability in ACRIDIDAE follows the law of homologous series, we can expect that the tendency to the phase variation observed in gregarious species should also be expressed in the non-gregarious grasshoppers. In fact, as we shall now see, the whole complex of colour, structural and biological variations, which constitute the phenomenon of phases and which have so far been considered as a peculiarity of the gregarious ACRIDIDAE, can be observed in the so-called "solitary" grasshoppers as well.

Analogies in Coloration.

Every one of the colour forms of *Chorthippus albomarginatus* described above occurs in a complete gamut of colours, without, however, changing the general type. These colour modifications are very unstable and consist mainly in the darker or lighter general shade. The green colour changes least of all; while the brown colour is subject to wide variations. The brown colour of the dorsum (in f. *hyalosuperficies*) and still more on the sides (in f. *hyalolateralis*) can become darker and even completely black (Plates XIX, XX, figs. 7, 9, 17); it can become lighter and reach pale grey, yellowish white and pale buff (Plates XIX, XX, figs. 4, 8, 10, 12, 14, etc.). These modifications are particularly noticeable in the brown f. *rubiginosa* (Plate XX, figs. 14, 15) and least of all in the green f. *viridis* (Plate XX, figs. 20, 21). As already stated, the green colour becomes only somewhat lighter and the black marks on the sides of the pronotum and abdomen are reduced to a minimum, or disappear altogether. The extreme forms are connected by a continuous series of intermediate ones. These forms are particularly well expressed in hoppers, but they can be seen in the adults as well.

It is particularly important that the relative abundance of the lighter or darker coloured forms in a population is most closely connected with its density. The greater the density, the higher is the percentage of blackish-brown forms, while in a scattered population light-coloured forms predominate.

This can be illustrated by the following observations made in June 1934 in the Kuitunsk district of Eastern Siberia in three stations, which, although they were only 100–200 metres away from each other, differed greatly in the density of the population.

Plot I was a flat area, with a rich mixed vegetation, which sprung up there after a birch forest had been cut down. The vegetation was not damaged by grazing, and the most abundant plants were *Fragaria collina*, *Carex pediformis* and various Papilionaceae. The soil was turf-like, and covered by plants to the extent of 70–80 per cent.

Plot III. Lying at a distance of 200 metres from the first. A strongly overgrazed ground with sparse vegetation of *Poa angustifolia*, *Agropyrum repens*, *Artemisia scoparia*, *Carex stenophylla* and *Festuca ovina*. The ground was mostly bare, only about 20–30 per cent. of the area being covered. The upper layer of the soil was dust-like in structure.

Plot II was in all respects intermediate between I and III.

The light forms of grasshoppers will be provisionally called *solitaria*, the dark ones *gregaria*, and the intermediate ones *transiens*, regardless of the race to which each individual belongs. The averaged results of the analyses of populations made at the third and fourth hopper stages are presented in Table VIII.

It will be seen that the percentage of the blackish-brown (*gregaria*) in the habitat with the sparse population (less than one individual per square metre) is 14·2 per cent., but that it increases to 37·3 per cent. in the population of 10–20 per square metre, and reaches 50–60 per cent. when the density is 100–150 per square metre.

The opposite is observed in the case of light-coloured forms (*solitaria*), which constitute nearly half the population when it is sparse, and only about 6 per cent. of it when it is dense. Intermediate forms (*transiens*) constitute from 20 to 40 per cent. of any population.

TABLE VIII.

Percentage of Phases in Three different Habitats.

Density of population per sq. metre			<i>gregaria</i>	<i>transiens</i>	<i>solitaria</i>
Plot I—Less than one	...	...	14·2	39·0	46·8
Plot II—10–20	...	...	37·3	42·4	20·3
Plot III—50–150	...	...	57·1	36·4	6·5

Similar interrelations between *solitaria*, *transiens* and *gregaria* are observed if the material is at first divided into the races described above. In this case, the differentiation is more strongly expressed in the brown race (*f. rubiginosa*) and least in the green one (*f. viridis*), while *f. hyalolateralis* and *f. hyalosuperficies* occupy an intermediate position in this respect as in all others. It must be noted, however, that *f. hyalosuperficies* is in this respect nearer to *f. rubiginosa* than is *f. hyalolateralis*, which is nearer to *f. viridis*. This fact has already been seen in biometric characters, while here it is expressed in the greater phase variability of *f. hyalosuperficies*. In *f. viridis* there is a relatively high percentage of *transiens*, which is partly explained by the practical difficulty of classifying phase variants of the green race, in which the amplitude of variation is considerably smaller than in the brown one. If it is remembered that the green individuals occur mainly singly, and the brown ones in dense populations, it becomes clear that the greater morphological and colour variability of the brown race must depend on its greater tendency to mass outbreaks.

Such interrelations between the dark (*gregaria*) and light (*solitaria*) individuals, dependent on the density of population, have been observed in many places in 1933–34. The analogy with the phase variability of gregarious locusts was very striking, and it was necessary to arrange special experiments to discover whether the light individuals (presumed *solitaria*) if bred in crowded conditions would transform into the dark *gregaria*.

The experiments were made as already described (see page 501). Hoppers used in the experiments were either bred in the laboratory, or collected in the field in the first and second stage. About 120 hoppers were bred in isolation, but the majority of them died after the first or second moult, and these experiments were discounted. In 33 experiments grasshoppers were bred at least to the third stage, or even to the adult, and their results can be classified into three groups, as follows:—

1. Positive results, when a hopper considered to be either *gregaria* or *transiens* and kept singly could be ultimately definitely referred to *solitaria*.

2. Indefinite results, when there was no distinct lightening in coloration and the individual could only be referred to the same category as at the beginning of the experiment.

3. Negative results, when hoppers bred in isolation became darker, or the insect at the end of the experiment could be definitely classified as *gregaria*.

The results of these experiments are presented in Table IX.

The results can be considered as fairly convincing. It is true that indefinite results were about equal in number to the positive ones, but there was not a single definitely negative one. In no single case was there a darkening of the coloration or the production of ph. *gregaria*, which was invariably the case in crowded cages, as will be seen later. A high percentage of indefinite results is probably due to some peculiarities of the experimental material and to the conditions of the experiments. First of all, one cannot expect to find in grasshoppers the same sharp phase variability as in locusts. Secondly, in our experiments, particularly when the cages were placed directly on the grass, they sometimes enclosed flies and spiders, which could only influence the results unfavourably. Therefore, we consider that the results are on the whole satisfactory, though they are not fully conclusive.

TABLE IX.

Results of Breeding Hoppers of Chorthippus albomarginatus in Isolation.

	Positive	Indefinite	Negative	Total
<i>f. rubiginosa</i>	5	10	—	15
<i>f. hyalolateralis</i>	5	6	—	11
<i>f. hyalosuperficies</i>	2	1	—	3
<i>f. viridis</i>	1	—	—	1
<i>f. purpurata</i>	1	2	—	3
Total	14	19	—	33

On the other hand, very definite results were obtained by breeding the same species in crowded conditions. For these experiments, out of the 7-8 hoppers hatched from an egg-pod, one hopper was placed singly in a cage and the rest into a crowded cage. All the original hoppers were classified as *transiens*, because it is very difficult to refer hoppers of the first stage to a definite phase. In other experiments, hoppers of the second and third stage were collected in the field and were either all placed in a cage, or only those with *solitaria* coloration were selected.

The experiments commenced about the middle of May. The weather was extremely unfavourable, damp, cloudy and cold, with frequent rains, so that a very high mortality, sometimes up to 100 per cent., occurred in the cages. The immediate causes of mortality were not quite clear, and only in a few cases an infestation by fungus was discovered. Cannibalism, which Faure (1932) found common in locusts, was rarely observed, though the dead individuals were partly devoured by the others.

The results of the crowding experiments are presented in Table X.

In all the experiments *solitaria* was practically absent towards the end of development. The only exception was in the cage no. 90, in which only eight hoppers of 2-3 stage were placed. The greatest majority (nearly 90 per cent.) of the surviving hoppers were typical *gregaria*. If we consider that in the field in the extremely dense populations (up to 200 individuals per square metre) not more than 70-80 per cent. of individuals can be classified as ph. *gregaria*, then the results of the experiments are very striking. Particularly spectacular was the transformation in the cages nos. 116 and 119, in which we placed only the hoppers of first to third stages of definite *solitaria* coloration, viz., light grey, ochreous white, light yellow-green with scarcely perceptible brownish lateral stripes in only some of them. Nearly all of them became

at the end of the experiment brown-black with intense black lateral markings (see Plates XIX, XX, figs. 9, 10, 13, 15, 17, 19, 23, 25). Individuals of such a dark coloration occur in the field only rarely, but in the cages more than half were of that kind. In cage no. 119, which was painted greenish yellow, there occurred more frequently than elsewhere individuals with orange-yellow dorsum and black sides of the body (Plate XX, figs. 19, 25). Similarly coloured individuals were found in nature in the driest habitat with the highest observed density of population (about 200 per square metre). Judging by the analogy with gregarious ACRIDIDAE these forms should be considered as most typical ph. *gregaria*, and this is confirmed by measurements (see below).

TABLE X.

Cage no.	Description of initial material	Initial no. of hoppers	Final no. of hoppers	Phase of hoppers at the end		
				<i>sol.</i>	<i>trans.</i>	<i>greg.</i>
12	Bred from eggs ; all <i>transiens</i> ...	241	7	—	—	7
31	do. ...	22	2	—	—	2
50	do. ...	116	22	—	3	19
27	Collected in 1-2 stage ; 30% <i>gregaria</i> ; 40% <i>transiens</i> ; 30% <i>solitaria</i> ...	177	19	—	2	17
35	Collected at the same place in 2-3 stage	10	2	—	1	1
90	do.	8	6	1	4	1
95	do.	14	4	—	—	4
96	do.	12	7	—	2	5
120	Mixed material of 1-2 stage ; 50-55% <i>gregaria</i> ; 30-35% <i>transiens</i> ; and 5-10% <i>solitaria</i> ...	500	42	—	—	42
116	All <i>solitaria</i> of 1-3 stage ...	400	37	—	4	33
119	All <i>solitaria</i> of the 1-3 stage. Bred in cage painted greenish-yellow ...	500	39	—	3	36
Total ...		...	187	1	19	167
Percentage ...		...	100	0.5	10	89.5

Note.—Cages Nos. 12, 31, 50, 27, 35, 90 were of wire netting, cylindrical, measuring 12 cm. diameter by 20 cm. high. Cages Nos. 95, 96, 116, 119, 120 were rectangular, 16 × 20 × 24 cm.

The experimental data are insufficient to decide whether the colour of the background influences the coloration of grasshoppers as it does in solitary locusts (Faure, 1932), but this possibility must be borne in mind.

A definite darkening of the coloration under crowded conditions which we consider, by analogy with observations on locusts, as phase variation, was observed in all four races, although not to the same degree. More definite changes occurred in the brown race (*f. rubiginosa*) than in *f. hyalosuperficies*, while *f. viridis* was the least changeable, as can be seen if the figs. 14, 15, 16 and 17 (Plate XX) are compared with figs. 20 and 21 (Plate XX).

Similar, if less extensive, observations and experiments were made on *Aeropus sibiricus* and *Chorthippus biguttulus*. Field observations on *A. sibiricus* show that this species is more gregarious than *C. albomarginatus*, and at the same time more active and more variable in colour, approaching in these respects the true locusts more closely than any other Siberian grasshopper. In 1934 when we made a special study of the phase problem *A. sibiricus* was relatively scarce in our area and occurred singly, although a few years ago it was a mass pest. The specimens observed in 1934 were remarkable for their variety of coloration. Brown, orange, purple, greyish brown and green individuals occurred side by side, but light grey ones, with faintly marked black lateral stripes, were more common. In the years and areas of mass outbreaks of *A. sibiricus*, individuals of brown or orange-brown colour with intense black lateral stripes predominate. Breeding under crowded conditions resulted in a considerable general darkening and more intensive black spots.

Chorthippus biguttulus is equally subject to variations in colour, and a complete series of forms can be found in nature. In this species, more than in any other, an adaptation to the background is observed. On sand they acquire a greyish-yellow dotted coloration, on saltings white dots appear, in bush grass wholly green forms are common, etc. Individuals living singly are usually light grey (Plate XX, fig. 24), while the crowded ones acquire sharply defined black lateral stripes.

Finally, another fact well known to most students of grasshoppers must be mentioned. Grasshoppers infested by mites are always darker in colour than the others, and can be referred to ph. *gregaria*. This must be due to constant irritation by the parasite causing the grasshopper to make continuous attempts to shake it off. I have observed a darkening of parasitised individuals even in such species as *Chorthippus dorsatus*, in which no phase variation could be found.

All these facts present a complete analogy with the phase variability of locusts.

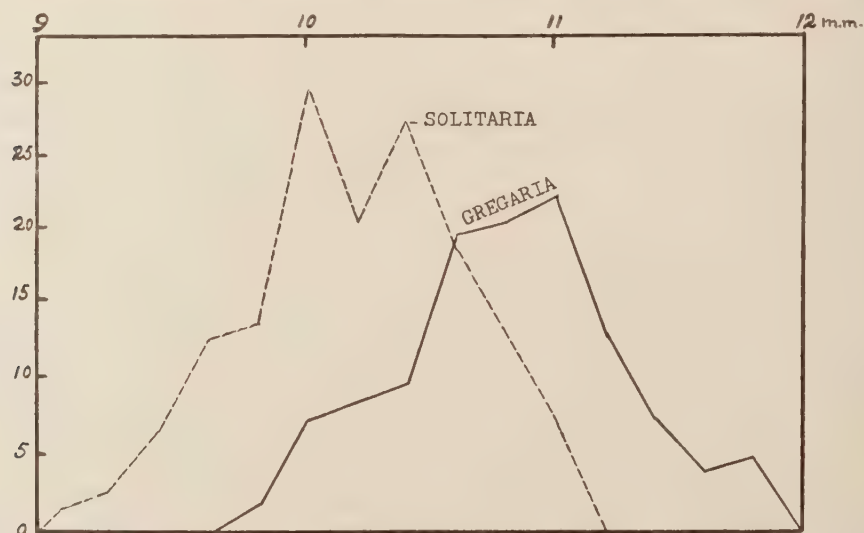


Fig. 1. Distribution curve of variations in the length of femur in the females of *Chorthippus albomarginatus*, DeG., ph. *gregaria* and ph. *solitaria*. (The length in mm. along the top; frequency numbers on the left.)

Analogies in Morphology.

Both the material bred in cages and that collected in the field, in the habitats described above, was measured. The specimens to be measured were classified into

four colour races, and within each race into the groups according to the colour of *gregaria*, *transiens* and *solitaria*. The individuals of different colour, mostly light grey, without the intense black lateral stripes, were regarded as *solitaria*; those of a dark colour with black lateral stripes and orange dorsum referred to *gregaria*; all the intermediate forms to *transiens*. Of course, it is not quite correct to take as a criterion the coloration alone, but our first aim was to find out whether the usual correlation between colour and biometrical characters holds good for our grasshoppers as well as for locusts.

The results of measurements of the field material (of all colour races together) are given in Table XI, while figs. 1 and 2 give the frequency curves for two of the measurements.

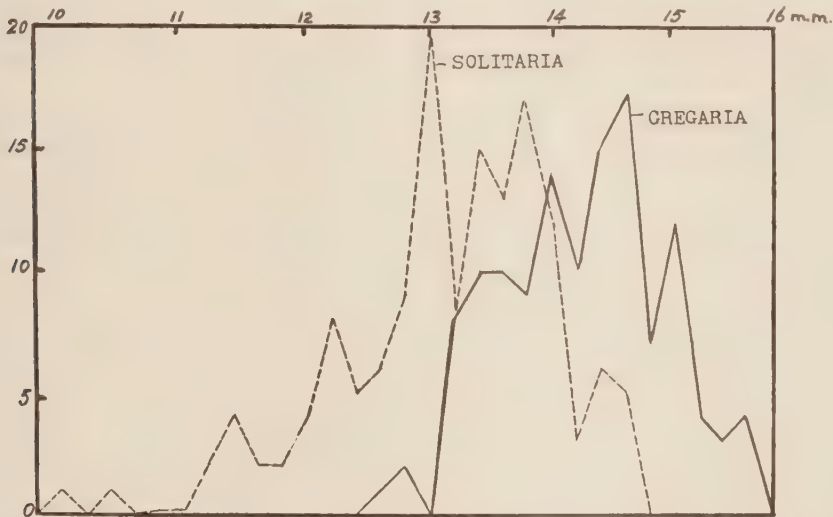


Fig. 2. Distribution curve of variations in the length of elytron in the females of *Chorthippus albomarginatus*, DeG., ph. *gregaria* and ph. *solitaria*. (The length in mm. along the top; frequency numbers on the left.)

It will be seen that *gregaria* and *solitaria* are very distinct. That the differences are significant is proved by calculating the ratio R. For the lines 1 and 3 this ratio equals 16.0; for 4 and 6 it is 8.0; for 7 and 9, it is 8.0; for 10 and 12, it is 3.8; for 13 and 15, it is 9.9; and for 16 and 18, it is 7.5.

The differences are essentially the same as in swarming locusts, namely (1) *solitaria* are smaller, both the femur and the elytron being shorter; (2) shortening of the elytra in *solitaria* proceeds more rapidly than that of the femora, the index being greater in *solitaria*, than in *gregaria*; (3) variability in *solitaria* is always greater than in *gregaria*, as can be seen by comparing the maximum and minimum figures.

It must be stressed here that the differences between *solitaria* and *gregaria* are in some respects opposite to those between *f. viridis* and *f. rubiginosa*. While the solitary mesophilous race *viridis* has a tendency to a larger size, the solitary phase in all races is smaller than *gregaria*. This fact appears to indicate a fundamental distinction between these two directions of variation, one being fixed and hereditary (race), the other acquired individually (phase).

Differences of the same kind are observed between the two phases within each of the races. There is, however, one important point. While individuals of *f. rubiginosa* are relatively easy to classify into phases, and those of *f. hyalolateralis* and

f. hyalosuperficies also do not present special difficulties, the classification is much more difficult in the case of *f. viridis*, owing to the already mentioned slight degree of difference even between its extreme phases. In practice we had to refer the majority of

TABLE XI.

Biometrics of the phases of Chorthippus albomarginatus (field material of all races).

				No. of specimens	Max.	Min.	Mean	σ	m.	
FEMUR (F)										
1.	<i>gregaria</i>	...	...	125	9.8	11.9	10.8	0.49	0.04	}
2.	<i>transiens</i>	...	...	158	9.5	11.7	10.5	0.44	0.03	
3.	<i>solitaria</i>	...	...	147	9.0	11.0	10.1	0.42	0.04	
ELYTRON (E)										
4.	<i>gregaria</i>	...	...	125	12.6	15.6	13.9	0.64	0.06	} ♀♀
5.	<i>transiens</i>	...	...	158	11.5	15.6	13.3	0.69	0.05	
6.	<i>solitaria</i>	...	...	147	9.9	14.9	13.1	0.93	0.08	
RATIO E/F										
7.	<i>gregaria</i>	...	...	125	1.47	1.21	1.36	0.066	0.006	}
8.	<i>transiens</i>	...	...	158	1.47	1.14	1.22	0.068	0.006	
9.	<i>solitaria</i>	...	...	147	1.45	1.11	1.23	0.092	0.007	
FEMUR (F)										
10.	<i>gregaria</i>	...	...	76	7.9	9.9	8.8	0.37	0.04	}
11.	<i>transiens</i>	...	...	152	8.0	10.5	8.7	0.4	0.03	
12.	<i>solitaria</i>	...	...	36	7.9	9.2	8.5	0.4	0.07	
ELYTRON (E)										
13.	<i>gregaria</i>	...	...	76	11.0	13.6	12.1	0.58	0.07	} ♂♂
14.	<i>transiens</i>	...	...	152	10.7	13.4	12.0	0.57	0.04	
15.	<i>solitaria</i>	...	...	36	10.2	12.6	11.4	0.76	0.013	
RATIO E/F										
16.	<i>gregaria</i>	...	...	76	1.64	1.29	1.39	0.066	0.007	}
17.	<i>transiens</i>	...	...	152	1.59	1.24	1.37	0.057	0.006	
18.	<i>solitaria</i>	...	...	36	1.64	1.13	1.29	0.073	0.013	

TABLE XII.

Length of Elytron in Females of Chorthippus albomarginatus, f. rubiginosa and f. viridis.

				No. of specimens	Min.	Max.	Mean	σ	m.
<i>rubiginosa</i>	<i>gregaria</i>	...	...	95	12.6	15.2	13.8	0.90	0.094
	<i>solitaria</i>	...	...	63	9.9	14.9	13.4	0.96	0.121
<i>viridis</i>	<i>gregaria</i>	...	...	20	13.2	15.6	14.1	0.89	0.20
	<i>solitaria</i>	...	...	13	12.9	15.0	13.9	0.92	0.25

f. viridis to *transiens*. It is of interest that this small extent of differentiation in *f. viridis* is confirmed by biometrical data. In order to reduce the amount of figures, it is sufficient to quote the length of the female elytra, which we have seen to be the most variable character (see Table XII).

That the figures of Table XII are not the result of a subjective error, due to the classification of the material into phase groups, is proved by the following. All the individuals swept in a habitat with dense population where ph. *gregaria* should be expected to predominate have been measured, and compared with similar mass material from the habitats with sparse population presumably mainly of the ph. *solitaria*. Both groups were measured without dividing them into phases (Table XIII).

TABLE XIII.

Biometrics of Chorthippus albomarginatus f. rubiginosa from two habitats with different density of population.

	No. of specimens	Min.	Max.	Mean	σ	m.
F						
1. Dense population ...	112	10.3	11.5	10.6	0.51	0.046
2. Sparse population ...	76	10.1	11.2	10.2	0.62	0.070
E						
3. Dense population ...	112	13.0	15.1	13.7	0.71	0.065
4. Sparse population ...	76	11.4	14.5	13.2	0.95	0.110
E/F						
5. Dense population ...	112	1.23	1.45	1.33	0.054	0.005
6. Sparse population ...	76	1.14	1.43	1.30	0.072	0.008

The ratio R equals 4.8 for the lines 1 and 2 ; 3.9 for the lines 3 and 4 ; and 3.8 for the lines 5 and 6.

The table shows that in spite of the mixed character of the populations, the differences between those in which *gregaria* and *solitaria*, respectively, predominated are quite clear and statistically significant.

The difference in the size of the two phases is also evident when the weight of individuals is compared (Table XIV).

TABLE XIV.

Average weight of individuals of two phases of Chorthippus albomarginatus.

					Number of individuals		Average weight in mgr.	
					♂ ♂	♀ ♀	♂ ♂	♀ ♀
<i>gregaria</i> ...	...	...	...	...	91	150	88.5	184.0
<i>solitaria</i> ...	...	...	...	...	29	84	65.0	115.0

The males of the gregarious phase are heavier than the solitary ones by 36 per cent., and the females by as much as 60. This difference is particularly noteworthy because the gregarious individuals live and feed in habitats with a poor vegetation, where there is a definite scarcity of food, while the solitaries live where food is always abundant.

No biometric studies were made on other species of grasshoppers. However, a rough comparison of the forms of *Chorthippus biguttulus* coloured as ph. *gregaria* with those like ph. *solitaria* shows similar relations, viz., the larger size of *gregaria*. We are inclined to think that similar results will be obtained in *Aeropus sibiricus* and possibly in other species.

Analogies in Behaviour.

According to Uvarov, the fundamental difference between the two phases is not in the colour and morphology, but in the biological characters, mainly in the mobility and readiness to migrate. In this respect also the forms which we consider as phases are distinct. To reveal the difference we have made periodical counts and analyses of the populations in two adjoining habitats, one with a very dense population and the other where the grasshoppers were practically absent, so that a migration from one to another was inevitable. Thus, on the 25th June on a pasture bordering on a wheat field, a dense band (over 200 per square metre) of 2nd and 3rd stage hoppers of *Chorthippus albomarginatus* was found. An analysis of a sample of 300 individuals showed 75 per cent. of f. *rubiginosa*, while their phase distribution was as follows: 68.1 per cent. *gregaria*, 29.3 per cent. *transiens*, and 2.6 per cent. *solitaria*. In the adjoining wheat field scarcely any hoppers were present. After three hot days hoppers were found in the wheat as well, the vegetation of the pasture being very poor. An analysis of the two populations produced the following results:—

	Pasture	Wheat field
	Per cent.	Per cent.
<i>gregaria</i>	66.2	92.0
<i>transiens</i>	30.1	7.5
<i>solitaria</i>	3.7	0.5

In the wheat almost exclusively *gregaria* individuals were found, which of course cannot be explained otherwise than by their greater mobility compared with *solitaria*. Similar observations have been made elsewhere.

Since the vertical displacements (climbing plants in the evening and descending in the morning) are more frequent in *Chorthippus albomarginatus* than in any other of our grasshoppers, we made an attempt to discover whether there are any differences in this respect between *gregaria* and *solitaria*. Sweepings were made in the same habitat in the daytime and at midnight, with the following results:—

	Day	Night
	Per cent.	Per cent.
<i>gregaria</i>	37	42
<i>transiens</i>	42	44
<i>solitaria</i>	21	14
No. of specimens ...	327	288

The figures cannot be regarded as convincing and more observations are necessary, but there appears to be some indication of a greater vertical mobility in *gregaria* than in *solitaria*.

Summary.

1. All the species of Siberian grasshoppers that have been studied in sufficient detail consist of a series of races exhibiting parallel coloration, structure and behaviour characters.

2. Every race of *Chorthippus albomarginatus*, Zett., *Aeropus sibiricus*, L., and of other species, has in its hopper and adult stage a series of colour forms analogous in their characters to the phases *solitaria*, *transiens* and *gregaria* of swarming locusts.

3. These colour forms are very unstable and undergo changes during the individual life due to the conditions of breeding.

4. Breeding in crowded conditions results in the predominance of dark-coloured forms, with black and sometimes with orange spots. Breeding in isolation, on the contrary, results in light forms of various colours.

5. No complete transformation of all the individuals in a population is observed in Siberian grasshoppers, and the intermediate forms represent a considerable portion of every population.

6. These colour forms, which can be considered as phases, differ also in their structural characters. Phase *gregaria* is larger and more long-winged than phase *solitaria*.

7. The phases differ further in their behaviour, ph. *gregaria* being more mobile and inclined to migrations, than ph. *solitaria*.

8. Every species and every race which have been studied exhibit a potential ability to produce phases, but this ability is not equal in all species and races. Those species and races which, owing to their habits and to the conditions of their habitats, can multiply in masses in restricted areas are more inclined to phase variability.

9. Races and phases have some features of resemblance and of difference, which can be summarised, as follows :—

Races.

1. Inheritable. Not subject to changes due to the conditions during the individual life.

2. The brown xerophilous race appearing in large numbers is more long-winged and more mobile, but smaller than the green race living singly.

Phases.

1. Non-inheritable. Subject to changes during the individual life according to the density of population during development.

2. The gregarious phase developing under crowded and dry conditions is also dark-coloured, more long-winged, and more mobile, but larger in size than the light-coloured solitary phase developing in scattered populations.

Conclusions.

The data presented in this paper suggest that the inheritable variations inside the species, following the law of homologous series, and the individual phase variability, as defined by Uvarov (1928), do not contradict each other and are found probably in all the ACRIDIDAE, though in different degrees. The degree of phase variability is very different according to the species and varies from the striking structural and biological transformation in *Locusta migratoria*, L., to the small, but wholly analogous, changes in non-swarming grasshoppers. The degree of phase variability is directly connected with the possibilities for a given species or race to develop in a restricted space in numbers exceeding those which can find sufficient food in the place of hatching. We believe that this explains both the origin and the biological meaning of the phase variability, which can be regarded as a special adaptation.

However, further progress in the studies of phase variability can be expected primarily from exact investigations of its physiological aspect.

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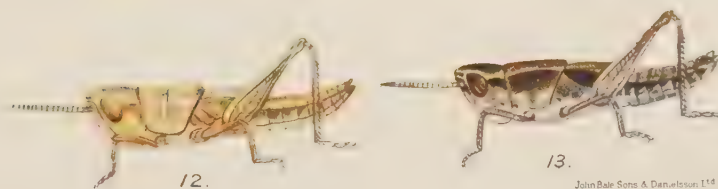
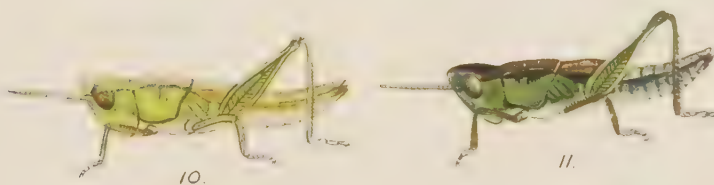
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EXPLANATION OF PLATE XIX.

Chorthippus albomarginatus, DeG.

- Fig. 1. Second stage hopper of the ph. *transiens*, most common in the field.
,, 2. First stage hopper of the ph. *solitaria*.
,, 3. First stage hopper of the ph. *gregaria*.
,, 4. Fourth stage hopper (♀) of the ph. *solitaria* bred in isolation.
,, 5. Fourth stage hopper (♀) of the ph. *gregaria* bred from the same egg-pod as the preceding one but in a crowd.
,, 6. Fourth stage hopper (♀?) of the ph. *transiens* taken in the field.
,, 7. Forma *fuliginosa*, ph. *gregaria* (♀), taken in the field.
,, 8. Forma *hyalosuperficies*, ph. *solitaria* (♀), bred in isolation.
,, 9. Do., ph. *gregaria*, bred in a crowd.
,, 10. Forma *hyalolateralis*, ph. *solitaria* (♀), bred in isolation.
,, 11. Do., bred in a crowd.
,, 12. Fourth stage hopper (♀) of f. *rubiginosa*, bred in isolation.
,, 13. Do., bred in a crowd.

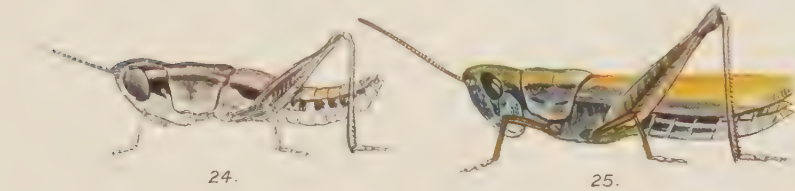
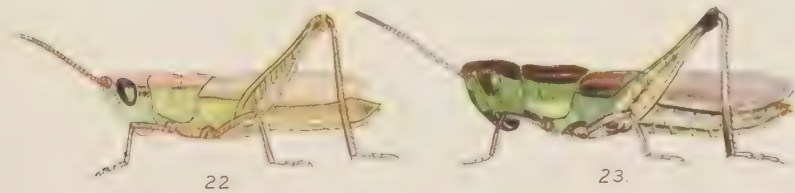
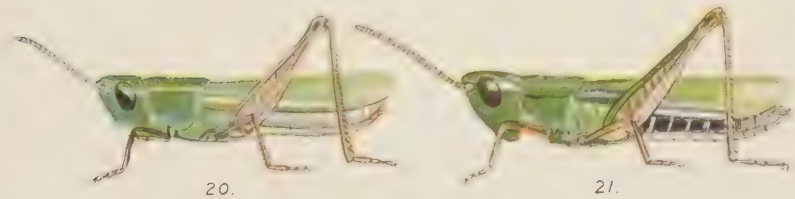


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EXPLANATION OF PLATE XX.

Chorthippus albomarginatus, DeG.

- Fig. 14. Forma *rubiginosa* (♀), bred in isolation.
,, 15. Do., bred in a crowd.
,, 16. Forma *hyalosuperficies* (♀), bred in isolation.
,, 17. Do., bred in a crowd.
,, 18. Forma *hyalolateralis* (♀), bred in isolation.
,, 19. Do., bred in a crowd.
,, 20. Forma *viridis* (♀), bred in isolation.
,, 21. Do., bred in a crowd.
,, 22. Forma *porphyrica* (♀), bred in isolation.
,, 23. Do., bred in a crowd.
,, 24. Forma *fuliginosa* (♀), bred in isolation.
,, 25. Do., bred in a crowd.



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SOME NEW COCCID-EATING GALL MIDGES (CECIDOMYIDAE).

By H. F. BARNES, M.A., Ph.D.

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In 1930 the available information regarding gall midges as enemies of the COCCIDAE was summarised in a paper published in the Bull. Ent. Res. (21, 1930, pp. 319-329). Since that time there have been several additions to our knowledge concerning such midges. Some of this knowledge was cited as an addendum in a later paper on gall midges as enemies of mites (Bull. Ent. Res. 24, 1933, pp. 215-228). It is proposed in this paper to bring this subject up to date by referring to published work and by describing some new forms that have been received for identification in the immediate past.

Diplosis sp. ♂, ♀

In 1921 Hall (Egypt. Minist. Agric. Tech. & Sci. Ser. Bull. 17, 1921) mentioned a *Diplosis* sp. which attacks *Phenacoccus hirsutus*, Green, in Egypt. In this connection it should be noted that *Diadiplosis indica*, Felt (1920) was described from specimens reared from larvae found preying on *Phenacoccus hirsutus*, Green, on mulberry at Pusa, India.

Dentifibula lacciferi, sp. n.

In March 1933 two females of a midge predacious on *Tachardia* sp., bred by N. C. E. Miller (8912, dated 15.ix.32) in Malaya, were received from the Imperial Institute of Entomology. In March 1934 a single Cecidomyid larva predacious on *Laccifer javanus*, Chamb., was received from the same source (9117). In June 1934 a series of pinned specimens reared by N. C. E. Miller (9117, dated 7.ii.33) from similar larvae was received from the Imperial Institute of Entomology.

An examination reveals the fact that these midges are closely allied to *Dentifibula ceylanica*, Felt, and *D. obtusilobae*, Felt. These latter were reared from twigs infested with Coccids and are lighter in colour than the midge in question. It is proposed to describe the midges reared by N. C. E. Miller as *Dentifibula lacciferi*, sp. n., and provisionally to associate with this species the two females (8912) previously reared from *Tachardia* sp.

Description.

Male.—Length about 1 mm. Antennae: about one-half longer than the body, brown, 2+12; each flagellar segment binodose, each node with a ring of long stout setae and a ring of circumfila with long loops reaching almost to the base of the next node and slightly shorter than the setae; 1st and 2nd flagellar segments fused; the 3rd flagellar segment with stem and neck equal, about twice as long as broad and about as long as the nodes; stem and neck of 10th flagellar segment equal, about three times as long as broad, the same length as stem and neck of 3rd flagellar segment. Palpi indistinct: 1st segment approximately quadrate; 2nd longer, about two and a half times as long as broad; 3rd and distal slightly longer, about the same width. Wings: hairy, rather broad; 3rd vein straight, reaching costa just before or at tip of wing, interrupting costa at margin of wing; 5th vein forked. Legs brown, hairy; claws all simple, strongly curved, distinctly longer than empodium. Abdomen dark brown, contents stain crimson in balsam preparations. Genitalia: basal clasp segment slender, about three times as long as broad, with small setose lobe on inner surface towards the base and indistinct small distal lobe; distal clasp segment

swollen basally, long, narrow, slightly curved, normal; dorsal lamella with a few setae, deep V-shaped emargination, each lobe broadly rounded; ventral lamella with a few setae, broadly rounded; style long, narrow.

Cotypes, Cecid. 2443-45.

Female.—Length about 1 mm. Antennae: 2+12, each flagellar segment with cylindric basal enlargement and neck, each enlargement with two rings of setae and circumfila, the distal ring of circumfila with short loops; 1st and 2nd flagellar segments fused; neck of 3rd flagellar segment between three and three and a half times as long as broad, slightly shorter than basal enlargement which is constricted and about twice as long as broad; distal segment about twice as long as broad, without appendage. Palpi about as in male. Ovipositor with long narrow setose lobes. Otherwise about as in male.

Cotypes, Cecid. 2446-48.

Other specimens, Cecid. 2449 and 2450.

Larva.—With predacious mouth-parts.

Cecid. 2451.

Habitat. Cotypes, predacious on *Laccifer javanus*, Chamb., Bukit Badong, Malaya.

Associated females, predacious on *Tachardia* sp., 28½ mile Kuala, Selangor Road, Malaya.

Larva, predacious on *Laccifer javanus*, Chamb., K. Lumpur, Malaya.

Coccodiplosis citri, sp. n.*

A tube of midges reared by J. S. Taylor from *Pseudococcus citri* in Pretoria during April 1933 was received from the Imperial Institute of Entomology in January 1934.

These specimens belong apparently to the genus *Coccodiplosis*, de Meijere (1917), which was erected for a species of gall midge, *C. pseudococci*, de Meijere, found feeding on *Pseudococcus adonidum*, *P. citri* and *P. crotonis* in Java. In Felt's key to genera (1925), this genus falls in the *Kalodiplosis*, Felt, *Mycocecis*, Edw., and *Kamptodiplosis*, Felt, group; while in Kieffer's key (1913) it falls next to *Calodiplosis*, Tav.

The species under consideration differs from *C. pseudococci*, de Meijere, in the following characters: the distal extremity of the ventral lamella in the male genitalia is convex instead of concave; the tooth on the claws is bigger and the claws themselves are more bent; the upper branch of the 5th vein is continuous; the shape and proportions of the palp segments are different; and finally the midge is considerably larger in general size. It is proposed to describe this species from Pretoria as *Coccodiplosis citri*, sp. n.

Description.

Male.—Length about 1.25 mm. Antennae: presumably 2+12; each flagellar segment binodose, the proximal node globular with a ring of circumfila, loops moderately short, and one ring of long setae just over twice as long as loops; the distal node elongated, slightly constricted, with two rings of circumfila, loops moderately short, and an irregular ring of setae just about twice as long as loops in distal ring; the proximal nodes on the 1st and 2nd flagellar segments elongated, thus resulting in a reduction of the stem; 1st and 2nd flagellar segments fused; stem of 3rd flagellar segment about one and one-half times as broad as long, transverse, neck just under one and one-half times as long as broad; stem of 8th flagellar segment slightly longer than broad, neck about twice as long as broad. Palpi: three segments; 1st cup-shaped, small, broader than long, with long setae, slightly overlapping 2nd; 2nd about twice as long as broad and about twice as long as 1st; 3rd and distal segment slender, four to five times as long as broad, pointed, narrower than and quite half as long again as 2nd; 2nd and 3rd segments with moderately long setae. Wings: 3rd vein straight,

except for a slight downward curve distally, reaching and interrupting margin just before apex of wing; 5th vein branched, upper branch complete, continuing direction of stem. Legs hairy; claws strongly curved, bifid on fore-, mid- and hind-legs, empodium inconspicuous. Genitalia: basal clasp segment broad, short, with long setae, without any lobe; distal clasp segment short, pubescent and with short setae, "ongle" well defined with suggestion of pectination in addition; dorsal lamella narrowly and deeply divided, each lobe large, broadly rounded, with short setae; ventral lamella entire, broadly rounded, with short setae; style long, moderately broad.

Cotypes, Cecid. 2154-60 inclusive.

Female.—Length about 2 mm. Antennae: 2+12; each flagellar segment cylindrical with short neck, two irregular rings of long setae, circumfila applied; cylindrical portion of 3rd flagellar segment about two and a-half times as long as broad, neck slightly broader than long, the width a little more than half the width of the cylindrical portion; that of 10th flagellar segment slightly over twice as long as broad, neck about as long as broad and half the width of cylindrical portion of segment; 12th flagellar segment about three times as long as broad. Palpi: similar to male; 1st segment small, cup-shaped, about twice as broad as long; 2nd about twice as long as broad and slightly more than twice as long as 1st; 3rd and distal segment slender, just over four times as long as broad, pointed; 1st segment with long setae; 2nd and 3rd with moderately long setae. Ovipositor with broadly rounded setiferous lobes, and small basal lobe also with long setae. Otherwise about as in male.

Cotypes, Cecid. 2161-5 inclusive.

Habitat.—Ex *Pseudococcus citri*, Pretoria, S. Africa.

In addition to the above described midge, it is as well to recall that the following species of gall midges are already recorded as attacking *Pseudococcus citri*:—*Acaroletes pseudococci*, Felt (1914), in Sicily, *Coccodiplosis pseudococci*, de Meijere (1917), in Java, *Dicrodiplosis coccidarum*, Felt (1911), in Porto Rico, *Lobodiplosis coccidarum*, Felt (1911), in St. Vincent, and an undescribed Cecidomyid in Palestine (Bodenheimer & Guttfeld, Z. angew. Ent., 1929, pp. 122-31). These latter authors also record a second Cecidomyid on p. 133, but from the illustration (Abb. 24) this appears not to be a Cecidomyid at all but rather a Mycetophilid fly. Whether this fly really attacks *P. citri* must remain an open question for others to decide.

Lobodiplosis pseudococci, Felt (J. New York Ent. Soc., 41, 1933, 87-9).

The male and female of this species were described from larvae predacious on the pineapple mealybug, *Pseudococcus brevipes* (= *bromeliae*, Bouché (auctt.)). The actual specimens described came in 1932 from the Hawaiian island of Oahu into which the species was introduced from Mexico in 1930. Since that time it has been distributed over the Islands. According to Schmidt (Proc. Hawaiian Ent. Soc. 8, 1934, p. 360) this species was introduced by Fullaway and is now known to be well established in some of the pineapple fields. Bryan (*loc. cit.*, pp. 406-7 & 447) mentions this species in his review of the Hawaiian Diptera. Two other species of gall midges have previously been recorded from this mealybug, namely *Diadiplosis pseudococci*, Felt (1921), in British Guiana, and *Schizobremia formosana*, Felt (1926), in Formosa.

Triommata coccotroctes, Barnes (Bull. Ent. Res., 22, 1931, 205-7).

In January 1934 two pinned specimens were received through the Imperial Institute of Entomology from E. Hargreaves. They were labelled "ex mealybug 553, Njala, Sierra Leone, emerged 22.12.32." Examination showed that these (♂, Cecid. 2414; ♀, Cecid. 2415) were further specimens of *T. coccotroctes*, Barnes. This species was originally described from specimens reared in 1930 from the same locality. In this case also the mealybug was unidentified.

Schizobremia coffeae, sp. n.

In March 1934 a tube of midges labelled "ex mealybugs on coffee, Kampala, Uganda, February 1933, H. Hargreaves no. 0472" was received for identification from the Imperial Institute of Entomology. In the tube there were one male and four females of a *Schizobremia*, Felt (1926) and, in addition, one female (Cecid. 2324) of another Trifila genus. This latter may possibly be a specimen of *Arthrocnodax walkeriana*, Felt (1915). This species, which was originally reared from a species of *Pseudococcus* on coffee in Ceylon, may be distinguished from the *Schizobremia* by reason of all the claws being simple and the empodium being of about the same length as the claws. There is one other record of a Cecidomyid feeding on a Coccid on coffee, namely that by Koningsberger & Zimmerman (Meded. u. 'Slands Planteum, **44**, 1901, p. 34, pl. 1, figs. 19 & 20), who record and figure a Cecidomyid as parasitic on *Pulvinaria psidii* in Java on coffee.

Two species of *Schizobremia* have been described, namely *S. formosana*, Felt (1926), and *S. malabarensis*, Felt (1927). The former was originally reared from pineapple infested with a species of *Pseudococcus* in Formosa by R. Takahashi. In 1930 Professor Takahashi wrote sending further midges reared from *P. filamentosus*, Ckll., and also stating that *S. formosana* was originally reared from *P. brevipes*, Ckll. (= *bromeliae*, Bouché (auctt.)) on pineapple. The midges in this latter sending (Cecid. 1519-26) from *P. filamentosus* appeared, without examination of the type specimens, to be identical with *S. formosana*, Felt. *S. malabarensis*, tentatively referred to this genus, was reared from *Pseudococcus virgatus* (= *Ferrisia virgata*, Ckll.) on pepper, Taliparamba, N. Malabar.

It is proposed to describe the *Schizobremia* as *S. coffeae*, sp. n.

Description.

Male.—Length about 1 mm. Antennae: presumably 2+12, the flagellar segments binodose with one ring of regular circumfila on the basal node as well as a ring of long stout setae nearly three times as long as loops of the circumfila, distal node elongate with two rings of regular circumfila and an irregular ring of stout setae about twice as long as distal ring of loops; 1st and 2nd flagellar segments fused; stem of 3rd flagellar segment transverse, about twice as broad as long, neck about as broad as long, only slightly less broad than stem, lengths of basal node, stem, distal node and neck about as 11:3:17:6. Palpi: three segments; proximal segment small, quadrate; 2nd about twice as long as broad; distal segment about twice as long as 2nd, slightly more slender. Thorax dark brown dorsally, yellowish on sides. Wings: hyaline, 3rd vein interrupting costa at tip of wing; 5th vein forked, upper branch continuing direction of stem. Legs, more straw than brownish; fore-claws, with heavy tooth, mid- and hind-claws simple, empodium minute. Genitalia: basal clasp segment stout, with setae; distal clasp segment short, broad, pectinate; dorsal lamella narrowly and deeply emarginate, each lobe broad and rounded; ventral lamella broad, slightly emarginate; style long.

Type, Cecid. 2319.

Female.—Length about 1.25 mm. Antennae: 2+12; each flagellar segment cylindrical with short necks; 1st and 2nd flagellar segments fused; cylindrical portion of 3rd flagellar segment about two and a-half times as long as broad, neck about as long as broad; terminal segment about three times as long as broad. Palpi: about as in male. Abdomen hairy, yellowish. Ovipositor with two broad lobes. Otherwise about as in male.

Cotypes, Cecid. 2320-23 inclusive.

Habitat.—Ex mealybug on coffee, Kampala, Uganda.

Recently (June and July, 1935) the writer has received further specimens (males, Cecid. 2537, 2550-5; females, Cecid. 2538-42, 2556-8; pupae, Cecid. 2543, 2559;

larvae, Cecid. 2560-1; and host, Cecid. 2544) of this species attacking *Pseudococcus lilacinus*, Ckll., on coffee in Bukoba from A. H. Ritchie, Government Entomologist in Tanganyika Territory. In some of these specimens the ventral lamella of the males is distinctly emarginate. This species is therefore now known from areas on the north and west of Lake Victoria in Uganda and Tanganyika. Appended are some biological notes which Mr. Ritchie has kindly given me permission to include in this paper. I am grateful to him for this privilege.

"The predatorial larvae of this Cecidomyid are to be found deep within the mealybug colonies and feed attached to the ventral surface of the bugs. Where many bug colonies occur amongst the blossom and cherry clusters, pupation of *Schizobremia* takes place beneath a tough white webbing around and between the furcate blossom bases or near the stem end of the cherries: where mealybug occurs on the under-side of coffee foliage the white cocoons are fixed alongside the leaf mid-rib or where the principal lateral veins join the mid-rib. The sucked-out remains of the mealybugs are to be found clustered over the pupation webbing and around where the larvae have been feeding. Larvae of *Schizobremia* while first of a white colour change to a vivid turmeric just before pupation. Before emergence of the adult, the pupal case is thrust up through and protrudes half-way above the webbing or the mat of sooty mould associated with the mealybug colonies and splits forward behind the antennal casing. The eggs of *Schizobremia* are laid over the mealybug colonies, indiscriminately on the wax of the ovisacs. The eggs are capsule-shaped, squarely rounded at both ends, yellowish pink in colour.

"The observed secreted habit of feeding of the Cecidomyid larvae down within the bug colonies and from below the bug itself provides a measure of protection to the larvae against ants attending mealybug and which feed on the dorsal wax excretion of the mealybugs.

"According to the writer's observation, *Schizobremia* is a most useful predator of mealybug and occurs throughout the Bukoba coffee area. *Schizobremia* is itself attacked by a Hymenopterous parasite in its developmental stages and the exclusion of this parasite is essential if introduction of *Schizobremia* is undertaken to areas outside its present area of known distribution."

***Schizobremia jujubae*, sp. n.**

Four pinned specimens labelled "ex *Pseudococcus* sp. on *Zizyphus jujuba*, Rose Hill, Mauritius" were received in January 1934 through the Imperial Institute of Entomology from A. Moutia. They had been reared by R. Mamet in June and November 1933. Although the specimens are in poor condition (having originally been mounted dry, thus requiring remounting on microscope slides), it has been possible to place them in their presumably correct generic position, namely *Schizobremia*, Felt (1926). This species is very similar to that described above as *S. coffeae* from Uganda; but it may be distinguished most readily by the greater length of the stem on the 3rd flagellar segment in the male. It is proposed to describe the species from Mauritius as *S. jujubae*, sp. n.

Description.

Male.—Length about 1.25 mm. Antennae: dark brown, 2 + 12; each flagellar segment binodose, the proximal node slightly wider than long, with single ring of rather short circumfila and long stout setae just over twice as long as loops of circumfila, distal node not constricted or tapering, with two rings of rather short circumfila and one distal irregular ring of long stout setae, slightly longer than loops on distal ring of circumfila; 1st and 2nd flagellar segments fused; stem of 3rd flagellar segment transverse, slightly wider than long, about half as long as basal node, neck about as long as broad, lengths of basal node, stem, distal node and neck about as 11 : 5 : 17 : 7; stem of 10th flagellar segment about as long as broad,

neck slightly longer. Palpi: indistinct, with a few setae; distal (3rd) segment apparently twice as long as second; 1st segment half as long as 2nd. Thorax dark brown dorsally, yellowish on sides. Wings: hyaline; 3rd vein interrupting costa at tip of wing; 5th vein forked, upper branch continuing direction of stem. Legs brown: fore-claws with faint tooth, all claws bent at right angle, empodium minute. Genitalia: basal clasp segment with setae, stout, without lobe; distal clasp segment short, broad, "ongle" with sharp point and in addition a peculiar pectination, resembling that of *Olesiococcus costa-limai*, Borg. (1931); dorsal lamella deeply and narrowly emarginate, each lobe broadly rounded; ventral lamella broadly rounded, entire.

Cotypes, Cecid. 2221 and 2222.

Female.—Length about 1.25 mm. Antennae: 2 + 12, each flagellar segment short, cylindrical, with short neck about as long as broad; 1st and 2nd flagellar segments fused. Palpi indistinct, about as in male. Ovipositor with broad rounded lobes with setae, and small basal lobe. Otherwise about as in male.

Cotypes, Cecid. 2223 and 2224.

Habitat.—Ex *Pseudococcus* sp. on *Zizyphus jujuba*, Rose Hill, Mauritius.

Schizobremia sp.

A male and female reared from *Saissetia hemisphaerica*, Hope Gardens, Jamaica, by C. C. Gowdey (1184, 11.x.26) have also been received from the Imperial Institute of Entomology for identification. Unfortunately they were dry specimens, which necessitated remounting and they are in poor condition.

The only species of midge whose larvae are recorded as feeding on *S. hemisphaerica* is *Dicrodiplosis coccidarum*, Felt (1911). Coquillett stated that they were associated with *Pseudococcus citri* and that other very similar specimens were reared from *S. hemisphaerica*, both sets of midges coming from Porto Rico.

The specimens from Jamaica at present under consideration do not belong to the genus *Dicrodiplosis*, Kieffer (1895), on account of their fore-claws only being toothed. However when *D. coccidarum* was described by Felt the labelling only stated "*Diplosis coccidarum*, Mayaguez, Porto Rico, 1889, August Busck," and it has not been proved definitely on what Coccid it fed. The original description was based on a solitary female. The Jamaican specimens (Cecid. 2463-4) may be tentatively referred to the genus *Schizobremia*, Felt (1926), but their poor condition precludes any definite determination.

GENERIC AND SUBGENERIC DIFFERENCES IN THE MOUTH-PARTS OF MALE MOSQUITOS.

By J. F. MARSHALL, M.A. & J. STALEY.

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The mouth-parts of male mosquitos are referred to in many text-books, but the descriptions given by various authors differ to a quite remarkable extent. This fact is particularly noticeable in regard to the maxillae and the mandibles. It is usually (and correctly) pointed out that maxillae are present in the male proboscis; but the statements made by different observers concerning the length of these organs are extremely discordant. As to whether the male proboscis contains mandibles in addition to maxillae, opinions are sharply divided, the majority of writers asserting (as we shall see, incorrectly) that such is not the case.

Dr. A. D. Imms having recently suggested to one of us that the discrepancies between the various published accounts of the male mouth-parts might be due to the existence of generic or even specific structural differences, we have commenced an investigation in respect of this possibility. Although, up to the present, we have examined the mouth-parts of certain British species only, the following notes relating to the information already acquired may perhaps be of interest. The species in question are listed below.

Genus	Subgenus	Species
<i>Anopheles</i>	<i>Anopheles</i>	<i>maculipennis</i> , <i>claviger</i> , <i>plumbeus</i>
<i>Aedes</i>	<i>Aedes</i>	<i>cinereus</i>
<i>Aedes</i>	<i>Finlaya</i>	<i>geniculatus</i>
<i>Aedes</i>	<i>Ochlerotatus</i>	<i>rusticus</i> , <i>punctor</i> , <i>detritus</i> , <i>cantans</i>
<i>Theobaldia</i>	<i>Theobaldia</i>	<i>annulata</i>
<i>Theobaldia</i>	<i>Culicella</i>	<i>morsitans</i> , <i>litorea</i>
<i>Culex</i>	<i>Culex</i>	<i>pipiens</i>
<i>Orthopodomyia</i>		<i>pulchripalpis</i>

The results of examining the mouth-parts of a number of males of each of the 14 species above mentioned may be summarised as follows:—

- (1) Maxillae were found in all specimens.
- (2) Mandibles were found in *all* specimens of genus *Orthopodomyia* and of subgenera *Anopheles* and *Theobaldia*; in *most* specimens of subgenera *Finlaya*, *Culicella* and *Culex*; but in *no* specimens of subgenera *Aedes* and *Ochlerotatus*.
- (3) The average length, both of the maxillae and (when present) of the mandibles, was found to vary greatly in different subgenera. In subgenus *Theobaldia*, for instance, the maxillae may be almost as long as the proboscis, whereas in subgenus *Aedes* they rarely attain one-twelfth of that length.
- (4) The limits between which the lengths both of the maxillae and (when present) of the mandibles vary in different species of the same subgenus were found to overlap too much to be utilisable for the purpose of specific diagnosis.

The observed lengths of the maxillae and mandibles are tabulated below. In the measurements given, the length of the proboscis (including the labella) is taken as 100. The mean (not average) lengths of the maxillae and mandibles of the various subgenera concerned are also shown diagrammatically in fig. 1. It will be noted that, both in the table and in the figure, the subgenera have been arranged so that the mean lengths of the maxillae appear in descending order of magnitude.

It should perhaps be mentioned that the maxillae of male mosquitos are devoid of teeth, and are (as well as the mandibles) of much flimsier construction than those of females.

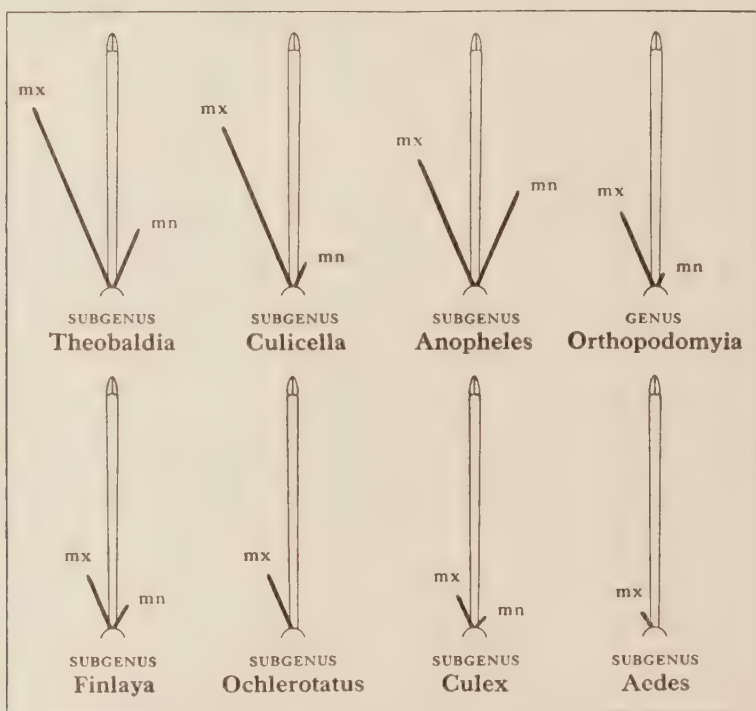


Fig. 1. Diagram showing the mean length of a male maxilla and (when present) of a male mandible in different subgenera of British mosquitos.

Genus or Subgenus	Length (proboscis 100) of					
	Maxillae			Mandibles		
	Min.	Max.	Mean	Min.	Max.	Mean
Subgen. <i>Theobaldia</i>	58	94	76	23	28	25.5
Subgen. <i>Culicella</i>	64	72	68	7	11	9*
Subgen. <i>Anopheles</i>	44	68	56	38	46	42
Genus <i>Orthopodomyia</i>	28	37	32.5	5	7	6
Subgen. <i>Finlaya</i>	20	28	24	9	14	11.5*
Subgen. <i>Ochlerotatus</i>	20	28	24	none found		
Subgen. <i>Culex</i>	9	19	14	5	7	6*
Subgen. <i>Aedes</i>	6	9	7.5	none found		

* Mandibles were found in most, but not all, of the specimens of *Culicella*, *Finlaya* and *Culex*.

The hypopharynx of the male is fused with the labium; and the labrum-epipharynx differs from that of the female in having a soft, furcate tip instead of a hard, pointed one.

OBSERVATIONS ON THE CONTROL OF INSECTS BY HAND-COLLECTION.

By RICHARD H. LE PELLEY,

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While hand-collection for the control of many different insects on a great variety of plants is widely practised throughout the world, the method has been the subject of remarkably little critical examination in the field; nor has there been up to the present, so far as the writer is aware, any statement adequately based on ascertained facts, proving or disproving its value in any particular case. Here follows an account of an experimental study of hand-collection for the control of *Antestia** on coffee, the results of which prove that the method is of little or no value in this case. The conclusions presented are considered likely to prove valid in other cases, and while similar studies are desirable in all other cases of large expenditure on hand-collection it is probable that much of this expenditure will similarly be shown to be unproductive.

There are various reasons why hand-collection, also called hand-picking, is a method that finds favour among planters, and often receives the tacit approval of entomologists. The planter believes that every insect caught is one less to eat the crop, and that therefore the value of the method is in direct proportion to the number of insects picked off; he finds it usually an easy method, because he gives it little supervision; he likes it because it entails no capital expenditure; and he observes on occasion that reduction of the pest follows, one such case weighing more in his mind than many where no reduction occurs.

In cases where an adequate control method has been difficult to find, the entomologist, while usually admitting the inadequacy of hand-picking, has nevertheless tended to accept the first of these reasons, and has given approval of the method without adequate trial of its value. The sort of qualified approval the general method has received from entomologists is well illustrated by Lefroy (1906):—"The simplest method is to pick the insects off the plants one by one and kill them. This is tedious but satisfactory and effective—it is a remedy far more suited to the ways of India where holdings are small, time is plentiful and patience unending than to other countries."

More recently d'Emmerez de Charmoy (1931), dealing with the Melolonthid beetle *Phytalus smithi* in sugar-cane, recorded that since 1911 nearly two thousand million insects had been destroyed in Mauritius, apparently chiefly or only by hand-collection and digging of larvae, at a cost of nearly a million rupees, and he stated that there could be little doubt that this expenditure was entirely justified. If such be the case, it is not shown by his figures. The area of cane attacked increased from about 3,000 acres in 1911 to 46,000 acres in 1930.

Recently the value of the method in certain cases has been questioned by certain writers, notably Myers (1931), who stated that "on some estates in Guiana and Trinidad gangs of 50 or more men, boys or girls are employed permanently to cut out 'dead-hearts' [shoots killed by borers] from which the larvae are extracted for counting and payment at so much a hundred. The economic value of this practice is extremely uncertain."

Thompson also refers to hand-collection, in an introduction to this publication, where he says "The observations made by Dr. Myers though still incomplete appear to indicate . . . the serious inefficiency of hand-collection as a means of controlling pests."

* *Antestia orbitalis* var. *lineatocollis*, Stål.

Control of *Antestia* by Hand-collection.

This method for the control of *Antestia* has been described by Anderson (1919), Wilkinson (1926), Le Pelley (1932) and probably others. Wilkinson recommended it as the best method to use, while the present writer stated that its value was undoubted, qualifying this by stating that its chief drawback was its expense. It will be shown that these recommendations should not have been made. The writer has been informed by planters that in the early days of *Antestia* attack on coffee in Kenya, possibly about 1915, the insect was often found to be present, sometimes in large numbers, in a small localised portion of the plantation, while the rest of the plantation was almost or quite free; and that in such cases they would keep a large gang of natives constantly searching this small portion day after day until the attack was overcome. Such a peculiar distribution of the insects, which perhaps never occurs to-day, is certainly the most favourable for hand-picking, and it is not considered impossible that in such a condition, given the "unending patience" mentioned by Lefroy, some adequate control might be obtained.

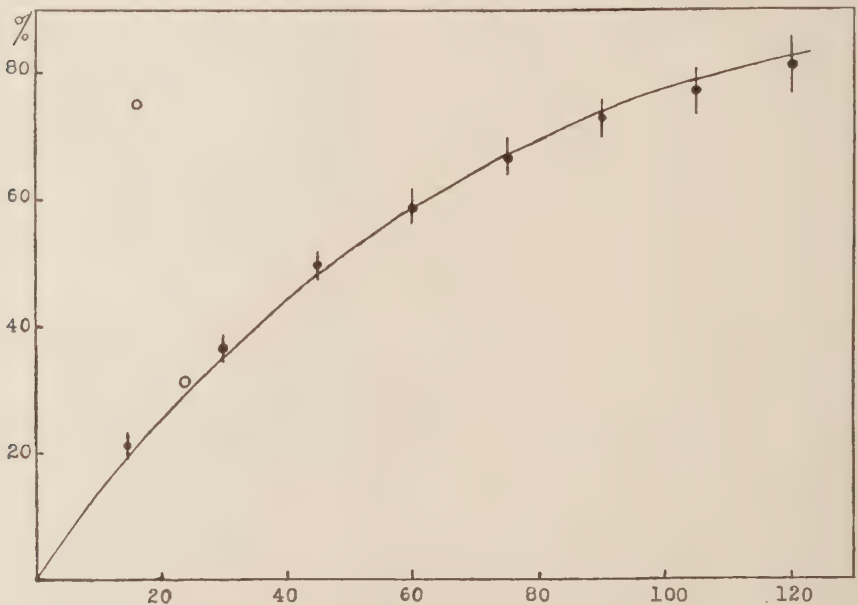


Fig. 1.

Hand-picking *Antestia* is practised to-day in all conditions of infestation, and the total sum spent in Kenya on the control of this insect by this one method in 1933 and the first months of 1934 was estimated to be not less than 100,000 shillings, representing the capture and destruction of about 67,000,000 insects. The figures and comments on them have been given in detail (Le Pelley 1934). It is safe to say that this expenditure was unjustified.

The experimental work in connection with this investigation consisted in a number of experimental hand-picks in the field, in which, of the total number of insects present, the percentages captured in known periods spent in the work were ascertained. The experiment which will receive most attention here was planned as follows. A small block of coffee consisting of forty trees in eight rows of five trees each was selected. Three rows of trees surrounding this block were heavily sprayed with pyrethrum kerosene extract to kill all the *Antestia* on them and prevent reinfestation of the forty. Each of the forty trees was then hand-picked for fifteen minutes

by two native labourers well acquainted with the work. Strict European supervision of the work was maintained. The insects obtained from each tree were kept separate, and the numbers of each life-history stage for each tree were recorded. After the forty trees had been searched in this manner, five of them were sprayed with pyrethrum extract to obtain the insects remaining on them. On the following day the remaining 35 trees were similarly searched by two boys for fifteen minutes, and five of these were sprayed. On the following day the remaining 30 trees were searched, and so on till the eighth day when the last five were searched and sprayed. The results obtained are represented graphically in fig. 1, where the time in minutes taken by two boys on one tree is plotted against the percentage hand-picked of the total *Antestia* present, the standard errors of the points being represented by vertical lines above and below the points, the positive error on one side, the equal negative error on the other.

It will be observed that the rate of increase in the percentage hand-picked, as the time spent on the work increases, is not constant, but decreases continually. In other words as the picking continues there is a progressive increase in the time required to obtain equal percentages of insects.

The trees in the experiment were large coffee trees, thick in branches and foliage. The insects are small and hide behind the branches and buds with great skill, even though they are much disturbed by smoke, such as was used in this experiment, and under the influence of which they frequently come out of hiding and make for the centre of the tree. Owing to the thickness of the trees and the small size of the insects it is inevitable that time and again the same area will be observed that has been observed before, and this fact explains why the increase in yield is not maintained at the same rate, because as the work progresses, increasingly large portions of the tree will have yielded insects and so will be examined fruitlessly.

An examination of the distribution of the points indicates that they are approximated by a curve. The curve is of the exponential type and the formula for it may be expressed thus $P=100(1-(V.e)^{-t})$ where "P" represents the percentage hand-picked of the total *Antestia* present, "t" represents the time in hours of two boys to a tree, "e" is the base of the Napierian logarithms, and "V" is a coefficient varying with the efficiency of the labour under different conditions. In a purely theoretical case, assuming the searching of the hand-pickers to be random and their industry to be continued throughout without flagging, this coefficient is unity and the formula becomes $P=100(1-e^{-t})$. The case under examination approximates fairly closely to the theoretical, the curve drawn having the formula $P=100(1-(0.89e)^{-t})$, and it is seen that the experimental data lie very close to this curve.

Applicability of the Formula in different Conditions.

In conditions such as existed in the above experiment, where the curve is lower throughout than the theoretical curve in ideal conditions, it seems reasonable to assume that time was wasted in the picking. On the other hand when the yield of insects is higher throughout the course of the curve it may be assumed that discrimination in the picking was possible. No method is readily available in the field for ascertaining either the waste of time or the extent to which discrimination is possible, but in practice such an attempt would appear to be unnecessary. Labourers strictly supervised, as in the experiments described, will on the whole only succeed in wasting a small portion of their time every day, and the curve, while below the theoretical, may be expected to have the same general form throughout. On the other hand when conditions of the coffee are such that some discrimination can be used in the searching, this too is likely to be fairly constant if conditions are not widely different and if they remain the same throughout the picking, and the curve

while above the theoretical may also be expected to have the same general form. This would require more detailed and extended experimental confirmation, but the results here given indicate that a measure of the factors causing the curve to be above or below the theoretical is given by the calculation of the coefficient "V" and that this may be expected generally (in conditions at all approximating to those of the experiment) to afford a sufficiently accurate means of judging the probable results of field practice.

An examination of the results obtained on single trees is possible because the yield of insects was kept separate. The data for eight individual trees is plotted in fig. 2. The points in each curve are joined for the sake of clarity.

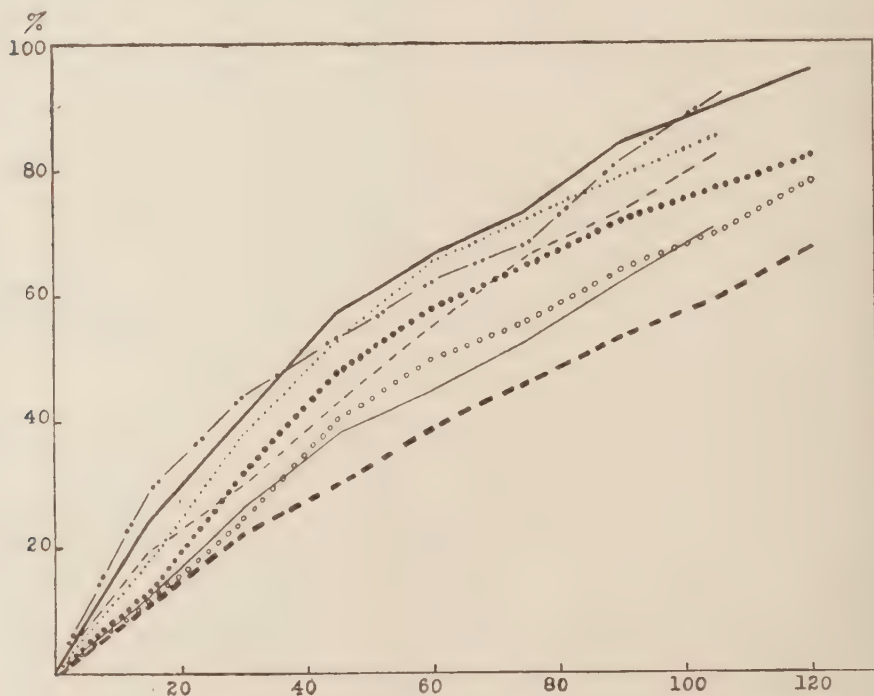


Fig. 2.

If we consider the tree with the lowest yield the formula calculated from the data available is $P=100(1-(0.615e)^{-t})$. This gives a curve to which the points representing actual yield of insects obtained in the field very closely approximate. This is shown in the following table where in column 2 are entered the percentages computed from the formula; in column 3 the percentages obtained in the field; and in the last column the deviation of the actual from the computed. The approximation is closer than might be expected in percentages based on single fifteen minute collections. Any other single tree would give results comparable to this.

The curve obtained is essentially similar to the curves postulated by Fiske (1910) and Nicholson (1933). Fiske speculating on what would happen in certain fixed conditions of parasitism plotted the number of eggs laid by a parasite against the number of unparasitised hosts. As the number of eggs laid increased there was a progressive increase in the possibility that the host chosen for oviposition had already

been parasitised and a curve was produced apparently similar to the above but for which no expression was obtained.*

TABLE I.

1	2	3	4
Time in hours " t "	Computed percentage obtainable $P = 100(1 - (.615e)^{-t})$	Percentage obtained by hand-pickers	Deviation of percentage hand-picked from percentage computed in column 2
0.25	12.0	12.0	None
0.50	22.6	22.4	-0.2
0.75	31.9	29.7	-2.2
1.00	40.1	39.0	-1.1
1.25	47.3	45.9	-1.4
1.50	53.7	53.2	-0.5
1.75	59.2	58.9	-1.3
2.00	64.1	67.2	+3.1

Nicholson used a similar curve originally obtained from arithmetical postulates, which he called the "competition curve." This was based on the success of animals in random searching, and he plotted the area traversed, representing the total amount of searching carried out by the animals, against the area covered, representing the area within which the objects sought were found. In the present experiments the native collectors represent the searching animals, the time spent on the work represents the amount of searching, and the percentage obtained of the total *Antestia* present represents the area covered. The correspondence of this curve obtained experimentally with one based on theoretical postulates in a different though similar problem is of interest. It is clear therefore that in so far as hand-collection approximates to random collection, as it must in nearly all cases with small insects on large plants, the conclusions drawn are valid. A case of very large insects on small plants such as large Lepidopterous larvae on small herbaceous plants, where the plants can be searched one by one and need not be searched again, would offer conditions in which the conclusions would not apply and in which hand-picking might possibly be effective.

Application of Results to Field-practice with *Antestia*.

Before showing how the results may be used to determine field-practice it is necessary to give some details of other similar experiments. In fig. 1 a point, represented by an open circle, will be seen near the lower part of the curve. This was a single point obtained in 1933 in an experiment in coffee of almost exactly the same condition. It will be seen how closely similar a result was obtained. There is one

* Not until after the preparation of this paper was completed was the writer able to consult W. R. Thompson's "La theorie mathématique de l'action des parasites entomophages et le facteur du hazard" in Ann. Fac. Sci. Marseille, 1924. Assuming a chance distribution of parasite eggs the expression obtained was $y = N(1 - e^{-\frac{x}{N}})$ where N represents the number of hosts, x the number of parasite eggs distributed and y the number of hosts parasitised.

further point at a considerable distance from the curve. This was obtained in very different conditions, the trees being heavily pruned. The averages were 16 minutes to a tree by two boys (costing 18s. per acre) and 75 per cent. captured of the total *Anolestia*. The yield of insects in this case is very much higher than would be expected from random picking, and it is obvious that in the conditions a considerable discrimination was possible. This is a case in which the formula is unlikely to apply sufficiently accurately to give results of value. But it may be pointed out that even in this case the cost of picking 75 per cent. is greater than the cost of killing 90 per cent. or more by pyrethrum-extract spraying.

The coefficient "V" used in the formula for the curve in fig. 1 was a mean of determinations made from all the points available. This gives a close general approximation of the theoretical curve to the experimental data. But the calculation of the value for "V" from only one point would be essential if the formula were to be used by planters to determine field practice. In Table II the deviations of the experimental results from those computed, using formulae derived from all the data and from one point only, are given.

TABLE II.

1	2	3	4	5
Time in hours per tree of two boys hand-picking	Percentage obtainable by hand-picking computed from formula $P=100(1-(0.89e)^{-t})$ obtained from average of all results	Deviation of percentage hand-picked from percentage computed in column 2	Percentage obtainable by hand-picking computed from formula $P=100(1-(0.912e)^{-t})$ obtained from one result only	Deviation of percentage hand-picked from percentage computed in column 4
0.25	19.8	+1.4	20.3	+0.9
0.50	35.7	+0.6	36.5	-0.2
0.75	48.5	-0.9	49.4	None
1.00	58.7	+0.1	59.7	-0.9
1.25	66.9	-0.4	67.9	-1.4
1.50	73.9	-0.5	74.4	-1.0
1.75	78.7	-1.2	79.6	-2.1
2.00	82.9	-1.8	83.8	-2.7

The fairly small deviations shown in column 5 indicate that one point, obtained in the field, entailing 2 or 3 hours work, will enable the minimum cost of picking any required percentage to be obtained with sufficient accuracy. What it may cost above this minimum will depend on the quality of the labour, and the amount of supervision that can be given. Planters who desire to convince themselves that hand-picking is not of value, or who wish to continue with the method, are advised to hand-pick carefully for a known time, and determine the percentage obtained, by spraying the tree afterwards with pyrethrum-kerosene extract. The formula may then be calculated from this information. In order to enable planters to use their own information without having calculations to make, it would be possible to prepare a graphical chart from which they could read off the information required.

While it is not considered necessary to analyse the figures for the separate instars in detail, it should be mentioned that the curves for all the instars of which enough insects were present to enable percentages to be determined were of the same form. The adults, as expected, were collected in the greatest proportions, the fifth instar in proportions somewhat less. The curves for both were above that for total insects shown in fig. 1. The curve for instar 4 was below that of the total, and that for instar 3, of which smaller numbers of insects were present, was markedly lower. Still smaller proportions of instar 2 were generally obtained, but there was only a small number of this stage. Only 25 individuals of instar 1 were present and this instar was not represented in the collections.

A mention must be made of costs, in order that the economic significance of the results may be evident. At the rate of two boys for fifteen minutes on one tree the work may be taken to cost 17s. an acre. The cost of obtaining 77 per cent. of the insects present was at the rate of 119s. an acre. This would have sufficed for at least six sprayings with pyrethrum-kerosene extract any one of which would have produced a kill of 95 per cent.

Former Plantation Practice.

On the subject of results obtained in plantation practice the writer has given some information (Le Pelley 1934). Plantation records are not frequently sufficiently accurate to be useful for analysis, but the writer was fortunate enough to obtain from a planter, to whom grateful acknowledgments are rendered, a series of figures representing fifteen months' detailed records of hand-pickings, which are of great interest and value. The work was done on an area of 35 acres of coffee. Hand-picking was continued for 15 months, no month passing without at least two days on which picking was done, the average being 13 days a month with a maximum of 27 days in one month. The number of "boy-days"* a month varied from a minimum of 9 to a maximum of 1,300 with an average of 607. The monthly yield of insects varied from a minimum of 4,500 to a maximum of 319,000 with an average of 155,000. The average monthly yield per boy-day varied from a minimum of 131 to a maximum of 500 with an average of 266. The average yield per boy-day in the last month, March 1934, was 289. The total cost was over 170 shillings. In June 1933 no less than 319,000 insects were removed from the small area of 35 acres, the average yield that month being 245 per boy-day, but despite this the yield in July was 128,000 with an average of 257 per boy-day, and in August it was 265,000 with an average of 304 per boy-day. The average yield per boy-day for every day in 1933 on which picking was done is shown in fig. 3.

The diagram shows large daily fluctuations, but the mean value was high throughout, and this shows that the insect was at least maintaining if not somewhat increasing its density. In February 1934, after 16 months picking 205,000 insects were captured with a boy-day average of 390. From 35 acres a total of nearly $2\frac{1}{2}$ million insects were removed or an average of nearly 100 insects per tree.

It is general knowledge among planters that *Antestia* often remains at a low density at which it does little damage for long periods. The writer has evidence, collected in detail over a considerable period in several localities, that even with considerable fluctuations in the physical environment, if the density of *Antestia* is low, it may remain practically unaltered for many months. It appears that the species normally tends to come into positions of equilibrium, at different densities according to the conditions, but which are always low. At times, for reasons not yet explicable, it grows away from this equilibrium, and increases in numbers until it may reach an "epidemic" state. In extreme cases it reaches a density considerably higher than

* A "boy-day" represents the labour of a man or woman or child for one day.

can be supported in the conditions and begins to decrease, sometimes rapidly, if left alone. Controlling factors are brought into play merely by the increase of the insects,

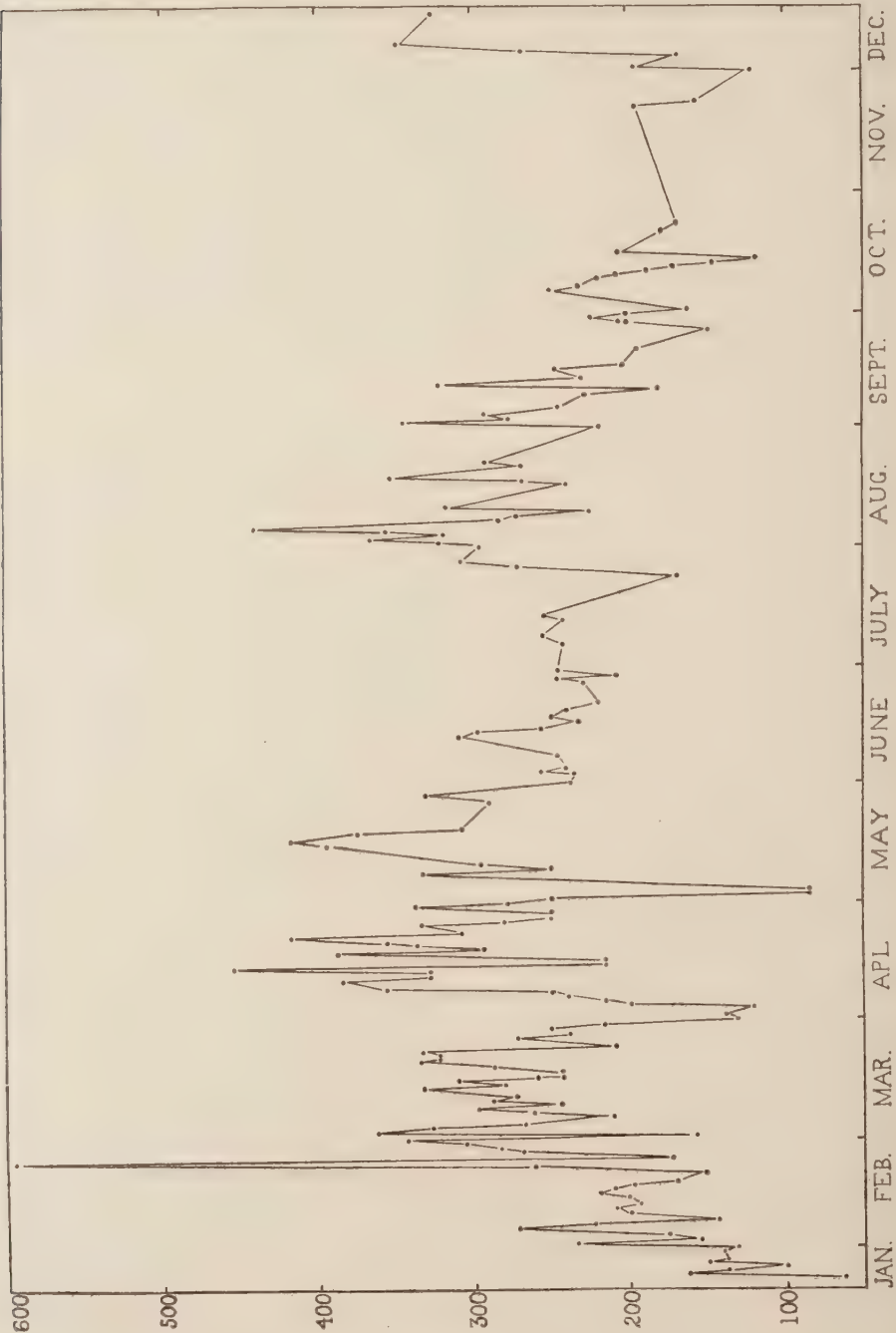


Fig. 3.

and other controlling factors almost certainly act more severely against them when the density is high. When the density is about 1,000 to a coffee tree it is clear that even overcrowding is an important controlling factor, positions for undisturbed egg-laying, and even for undisturbed feeding, being much less easy to find. Fluctuations in density at a lower level may partly be due to interaction with its several species of important egg-parasites, but adequate information on these questions is not yet available.

The case quoted above is the only one on record, and the only one known to the writer, in which *Antestia* has come to a density equivalent to a severe attack and has remained at this density for many months. In the lack of other explanation it seems reasonable to suggest that the hand-picking was a factor contributing to this condition. If sufficient insects were constantly removed to prevent a temporary increase to severely epidemic proportions, followed as this always is by a rapid fall often to small numbers, then a condition such as that described might occur. It may be that about 200 *Antestia* to a tree in the conditions of coffee prevailing was the limit which could be supported permanently, and that this was made possible by the continual removal of insects.

Summary.

The paper deals with the control of insects by hand-collection. An experimental study of the method as used against *Antestia* on coffee in Kenya is described. The rate of increase of the yield of insects collected falls off in a definite and measurable manner as the time spent on the work increases. The formula for the curve fitting the results is $P = 100(1 - (V.e.)^{-t})$ where "P" is the percentage collected of the total *Antestia* present, "t" is the time spent collecting, and "V" is a coefficient which has different values according to the conditions prevailing. In practice one careful experimental picking provides data for the calculation of the formula which may be used to determine the cost of hand-picking any percentage.

The results show that in theory 100 per cent. of the insects can never be obtained by hand-picking, and that in practice the cost of picking an adequate percentage is almost invariably prohibitive.

It is probable that the experimental results obtained will prove valid in other cases of hand-picking. Much of the expenditure on this method is unproductive.

Details of a thorough long-continued attempt to control *Antestia* on thirty-five acres of coffee by hand-picking are given. The attempt proved unsuccessful, and it is suggested that it may actually have been responsible for the maintenance of the severe attack.

The kind co-operation and assistance of a number of coffee planters are acknowledged. Except for the first experiments in 1933 Mr. H. Naismith Jones assisted me throughout, and the investigation owes a great deal to his careful supervision of much of the field work.

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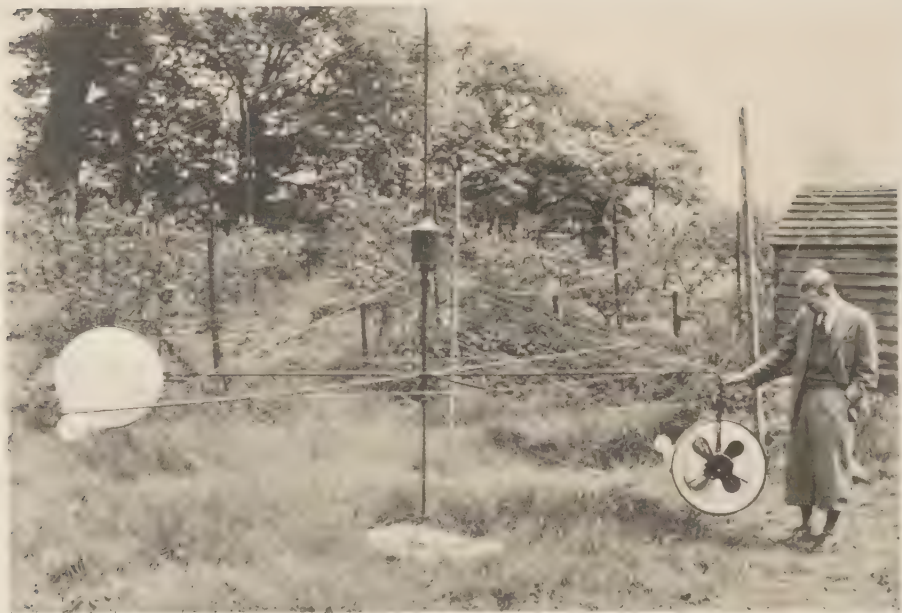


Fig. 1. General view of mechanical insect trap.

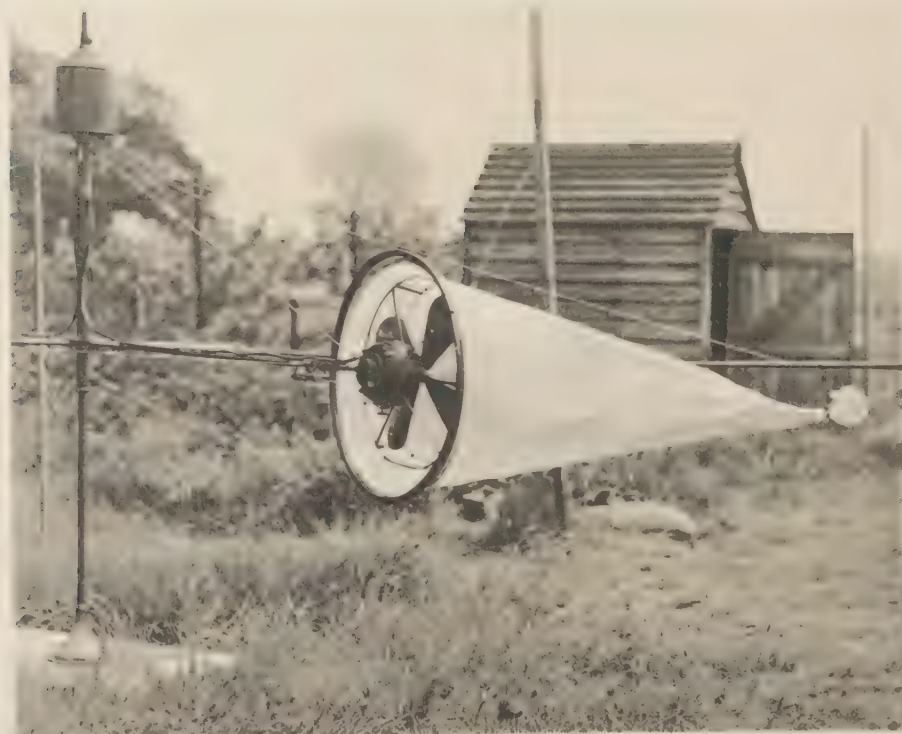


Fig. 2. Near view of upper fan and net.

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A MECHANICAL INSECT TRAP.

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(PLATE XXI.)

Introduction.

In the course of some work at Rothamsted on the activity and abundance of insects, in which a light trap was used as a method of estimating the numbers of insects in a state of activity, it appeared advisable to have a further trapping method which did not depend on phototropic response for its efficiency. A rough design for a mechanical trap was therefore drawn up by the senior author.

In October 1934 the junior author came to work at Rothamsted and took up the problem of the construction of the trap with such alterations and improvements as appeared necessary as the work proceeded.

As the trap has now reached a stage when its efficiency has been tested and found to be higher than we expected, and as it may be useful to other workers on the problem of insect populations, it is described below, with one or two examples of typical catches. The full discussion of the results obtained by its use at Rothamsted will form the subject of a later paper by the junior author.

The trap (Plate XXI) consists essentially of two long conical muslin nets fastened to the ends of a light framework about 12 ft. in diameter which is free to rotate and which can be raised and lowered so that the distance of the nets from the ground can be altered.

In the mouth of each net is an electric fan which drives a rapid current of air into the net and at the same time pulls the net forward so that the whole framework rotates horizontally round the central axis.

In the model constructed the nets are 22 in. in diameter at the mouth and 4 ft. 6 in. long. The fans are 16 in. in diameter, and the revolution of the fans is sufficient to cause the whole frame to rotate once in about 12 seconds or five times a minute. This means that the nets advance at a speed of about 3 ft. a second. The insects are drawn into the net chiefly by the inrush of air caused by the fan, but also to a lesser extent by the forward movement of the net.

The following is a description of the mechanical construction of the trap from which it is hoped that anyone who wishes to make one can do so without difficulty.

Mechanical Construction.

The fixed central axis of the trap is a straight tube of drawn steel 12 ft. high and $\frac{3}{4}$ in. in external diameter. It stands vertically on the cast-iron base of a standard G.E.C. electric fan, the connection between the two consisting of a peg of mild steel turned in the lathe to fit the inside of the tube and the socket in the base. A staggered series of holes is drilled diametrically through the tube at intervals of six inches starting from a point 2 ft. from the lower end.

The rotation of the horizontal framework carrying the fans and nets is achieved in the manner of a bicycle steering column. The framework, together with the electrical arrangements to be described later, is made as a complete unit which can be moved up or down the central axis and fixed by means of the pin (fig. 1, Pn) passing through one of the holes; the choice of the hole determines the height of the nets above the ground.

The inner non-rotating member of the column is a steel tube (Tb) 4 ft. 6 in. long, $\frac{1\frac{1}{2}}{16}$ in.* in external diameter, and with walls $\frac{1}{16}$ in. thick. A standard bicycle steering-head clip (A) is slipped over this tube with the ball-race uppermost and filled with $\frac{1}{8}$ in. steel balls. The clamping nut (B) is tightened so that the clip grips the tube about 5 ins. from the lower end. A loose steering-head ball-race (C) is then placed in position on top of the balls and above this again is a 2 ft. 6 in. length of stout tubing (D) with an internal diameter of $1\frac{1}{4}$ in. This tube fits closely over the shoulder on the loose ball-race and is therefore centred about the tube (Tb). It forms the rotating member of the column. To complete the column another ball-race and clip (E and F), with the necessary number of balls, are slipped over the tube in an inverted position and the whole is brought into alignment by tightening the clamping nut on the upper clip.

Six arms of steel tubing radiate out from the lower end of the rotating tube and the four longer of these are supported at or near their extremities by guy wires fixed to the top end of the rotating tube. The relative positions of the arms in the horizontal plane are maintained by a further system of guys connecting each arm to its neighbour.

The attachment of the arms to the tube is shown in section in fig. 1 and in plan in fig. 2. A 6-sided block of hard wood (G) of a thickness equal to the external diameter of the radial arms, and with a central hole slightly wider than the diameter of the column, is fixed round the latter at a point 1 in. from its lower end by means of three horizontally placed set-screws (H) engaging in tapped holes in the metal. Two circular plates of stout brass (K) are bolted one on each face of the wood to form a large bush. The ends of the radial arms are pushed into the space between the two plates and are secured by bolts (J) passing vertically through clearance holes in the four thicknesses of metal.

In order to prevent the arms from taking up positions tangential to the centre bush when the horizontal guy wires are tightened, the attachment of the two short arms (fig. 2, C) is made completely rigid by means of the strip iron supports (L) shown in the left-hand side of fig. 1. These lie above and below the arm and are fastened by two additional bolts (M), one through the bush and the other, with spacing washers, through the arm alone. This arrangement gives good rigidity when the guys are tightened and allows of a partial folding of the arms when the apparatus is to be moved in a confined space.

The lengths of the three pairs of arms (A, B, C, fig. 2) are 5 ft. 6 in., 8 ft., and 2 ft. 6 in. respectively; the tubing has walls $\frac{1}{16}$ in. thick and an internal diameter of $\frac{1}{2}$ in.

The fan motors are mounted on the end of the first pair, the longest arms (B) support the tail ends of the nets and the short rigid third pair are used as fixed points to which the guy wires are attached. The two longer pairs of arms are braced in the vertical plane by inclined guys fixed to brackets (Br, fig. 1) near the top end of the rotating tube.

Saddle-pieces and lugs of strip brass fixed by bolts passing through the arms are used to anchor the ends of the guy wires, which are of 16-gauge galvanised iron wire; each wire contains a small steel and brass strainer having a range of movement of about 2 ins. on which the final adjustments of tension are made.

The fans are the standard 16-in. induction pattern table model made by the General Electric Company. The motor and trunnion with its $\frac{1}{2}$ in. diameter peg are removed from the socket in the fan base and the peg is pushed into the end of the $\frac{1}{2}$ in. tube forming one of the arms (A) on the rotating beam; a bolt passing through the arm and the peg retains the motor with the fan in a vertical plane and

* This diameter was chosen as it exactly fits the standard bicycle steering-column ball-bearings and steering-head clips.

at the same time fixes the lug for the guy wire supporting the weight of the motor. When the second motor is similarly fitted to the opposite arm the whole beam is balanced and will rotate smoothly and without wobble on the small stand provided by the original base of one of the fans.

The fan blades face the long arms provided for the support of the tail ends of the nets so that when the current is switched on, air is drawn over the motors and the latter are pushed forward by the reaction of the flow.

A wooden hoop (fig. 2, D) 22 in. in diameter is placed concentrically round each motor and is fixed at three points provided by the horizontal arm and two brass rods which are screwed into the tapped holes in the motor casing; these holes are already present and are made available by removing the small lifting handle fitted by the makers.

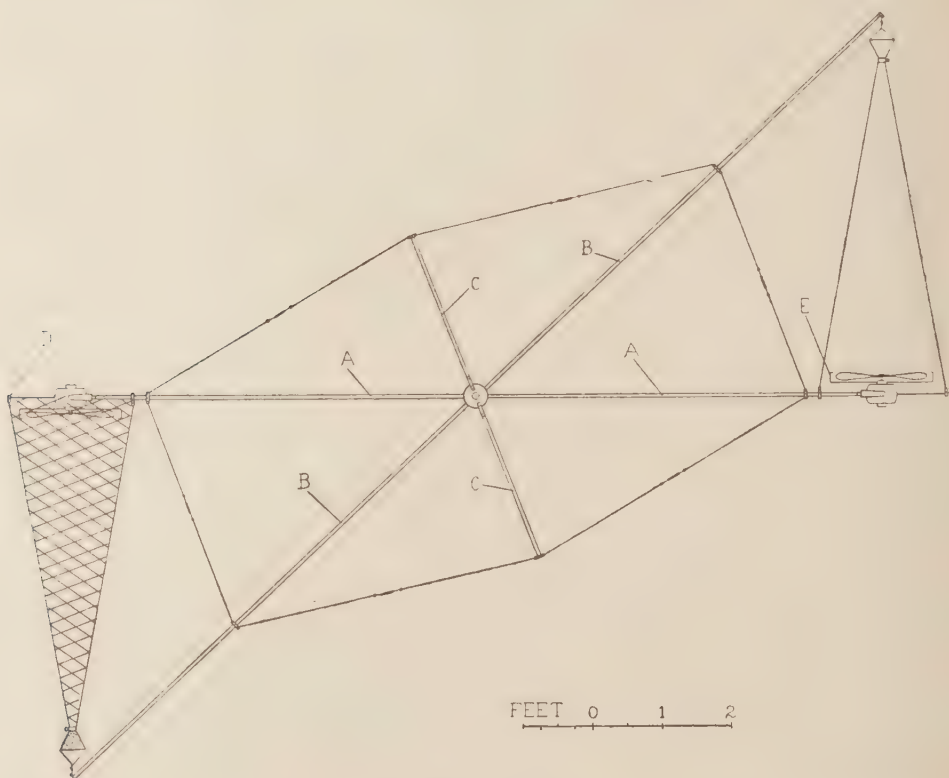


Fig. 2. Diagrammatic plan view of the trap showing the arrangement of the radial arms, fan motors and nets.

The mouth of the net is made of a hoop of similar size which is clipped on to the fixed hoop by three springy brass catches on the circumference. Three small bearing plates of sheet brass are screwed on to the edge of the net hoop so as to register with the catches and prevent the fabric of the net from being worn away at these points.

The stiff wire guard (E) supplied with the fan is retained to keep the net free from the edges of the fan blades in windy weather, but that portion of the guard which faces the blades is cut away to minimise losses due to eddy currents.

The motors are totally enclosed except for the small hole through which the flexible leads emerge, and were thought to be weatherproof. In wet weather, however, water was found to be entering through the spindle bearings and steps had to be taken to avoid this. The front and back inspection covers were loosened and turned round so that all the grease cups were inclined downwards. The end of the spindle carrying the fan blades was surrounded by a closely fitting hood of sheet brass with an opening below giving access to the greaser. Holes in the side of the hood allow the guard struts to pass through and these were packed round with rubber washers and insulating tape to prevent water draining in from above. The other end of the spindle was protected by a similar hood of simpler construction. Both hoods were fitted with lugs fastened down to the inspection covers by the bolts holding the latter to the body of the motor.

Current is supplied to the motors by means of contacts dipping into two concentric troughs of mercury fixed round the main axis just above the rotating column (fig. 1).

A thick teak board is turned in the lathe to give a circular block 4 in. in diameter with a $\frac{3}{8}$ in. hole in the centre. Two concentric troughs (T_1 and T_2) each $\frac{3}{8}$ in. wide and $\frac{3}{8}$ in. deep are then cut out of one face of the block at suitable distances from the edges and from each other; small channels in the wood leading to the side of the block communicate with the troughs and serve as drains when the mercury is to be removed, but are normally closed by short plugs. Two recesses leading radially from the centre are cut out of the lower face of the block and terminate respectively below the inner and outer troughs. Each recess contains a strip of brass connected electrically with the bottom of its trough by a brass bolt (N); the inner ends of the strips are fixed to two insulated bus-bars (S) passing vertically through the block and then bent round clear of the dipping contacts described below to form the terminals (Tr) for the power supply from the mains.

The channels in the lower face of the block are protected by the circular piece of wood (X). The lower side of this carries a steering-head clip (Q) by which the whole unit can be adjusted and clamped at the appropriate height on the tube Tb.

A wooden collar (W) is pushed tightly over the top end of the column and it carries two stiff brass rods (R) placed diametrically opposite each other and covered with rubber sleeving except for a small portion at each end; these pass upwards and outwards round the side of the teak block and are then bent through two right angles so that the tip of one rod dips into the mercury in the outer trough and the tip of the other into the mercury in the inner trough.

The leads from the two fan motors are fastened by insulating tape to the radial arms and pass up the side of the rotating column to be connected to the lower ends of the brass contact rods.

As the column rotates the brass rods rotate with it, their tips describing circular paths in the mercury and providing a continuous circuit for the current.

An ordinary 1-gallon paraffin can (Y) with a conical top is modified as a protecting cover for the troughs and contents. The bottom of the can is cut out neatly with a rolling type can-opener, the handle and spout are melted off and in place of the latter is sweated a bicycle steering-head clip (Z). This cover is then lowered over the troughs as far as possible without fouling the contact rods and is tightened on to the tube (Tb) by the clamping nut on the clip.

The Nets.

The nets are made of book-muslin and are 4 ft. 6 in. long and 22 in. in diameter at the mouth. The apex is fitted with a short zinc cone leading to a glass container whose open end is covered with muslin or net; a convenient form of container is

a glass funnel with a short wide stem which can be joined to the zinc cone by a contracting band of strip brass controlled by a wing nut.

A three-point yoke of cord is slipped over the glass funnel and hooked on to a small coil spring of piano wire fixed to the long arm of the rotating beam. The net is thus supported horizontally under a slight tension and at right angles to the fan blades.

The quality of the muslin used in the making of the nets has a great effect on the speed of the rotation of the trap and it is essential to use a fabric of regular mesh with the interstices free from stray fibres if a reasonable angular velocity is to be attained: if the resistance of the fabric is too high it may not be able to cope with the air delivered by the fans and some part of the air will be forced to escape forwards round the edge of the net, with a consequent reduction in the forward thrust and the speed of rotation. Two samples of muslin of approximately equal mesh but of widely differing texture gave speeds of $1\frac{1}{2}$ and $4\frac{1}{2}$ revolutions a minute respectively; tests with a delicate anemometer showed that in the former case air was escaping forward in an annular zone 1-2 in. wide round the mouth of the net, while in the latter case air was entering across the whole of the mouth and for a distance of about 15 in. down towards the narrow end.

The speed of $4\frac{1}{2}$ revolutions a minute was considered to be suitable for practical field work and a set of nets was made up using the second type of muslin. It has 45 meshes to the inch and is fine enough to retain all the smaller flying insects.

Installation in the Field.

In the field the top of the central axis must be supported by guys fixed in the ground to prevent the whole trap being blown over by the wind; four ropes or wires are taken out almost horizontally to pulleys on iron posts set obliquely outside the sweep of the nets and then descend to pegs driven into the ground. The guys should include strainers for setting the axis truly vertical.

The base should be placed on a level slab and packed round with sand-bags to prevent creeping. (More recently the fan base has been removed and the central tube dropped directly into a hole chiselled out of the slab.)

The height of the nets above the ground or vegetation can be adjusted within the limits set by the height of the central axis and the arrangement of the guy ropes. If the trap is set over a growing crop the nets can be raised at intervals by lifting the rotating framework and inserting the pin through the next higher hole in the axis.

Nets at different Levels.

In the original design the two nets were at the same level, but it was thought desirable to be able to use them at different levels if required. The motor of one side was removed from the end of the arm and an extension piece was substituted consisting of a $\frac{1}{2}$ -in. iron rod bent down through a right angle and attached to a short length of tubing. The motor and hoop were then re-fitted as before but in a completely inverted position. The length of the extension arm is such that the nets sweep through contiguous layers of air.

The tail end of the net is supported by a light wooden rod attached at right angles to the end of the long arm. The rod extends above the latter and is guyed forwards from its top end to the motor arm, so that the forward pull of the tail end of the net on the bottom end of the rod is balanced by an equal and opposite pull on the top end. A lead weight of appropriate size is fastened to the opposite motor arm to counterbalance the additional weight of the parts comprising the extension arm.

Effect of Wind.

The trap has been used for the most part in its modified form with the nets at different levels and the lower one just above the ground. The speed of rotation is but little affected by light winds, although small variations are produced by gusts. The effect of strong gusty winds is more marked; the upper net is more exposed than the lower one and is frequently brought to a standstill facing the wind for periods of 10 to 30 seconds during peaks in the wind velocity. On the other hand the rotation may be considerably accelerated if the peak comes when the upper net is travelling for the moment in the direction of the wind. The final effect of the wind is a definite decrease in the average number of revolutions per minute and a partial loss of the regularity of motion upon which the value of the trap depends.

Passage of Insects through the Fan Blades.

Early tests with the trap showed that its efficiency was much higher than was anticipated. Only a very small percentage of the insects caught are damaged in their passage through the fans. (The speed of the fans is given by the makers as 1,200 r.p.m.) Honey-bees, large Tipulids, moths, and even small tortoiseshell butterflies have been found in the glass funnels in perfect condition and apparently none the worse for their experience. Those few insects which are stunned by contact with the blades are caught by the mouth of the net and either remain sticking to the muslin or are eventually blown back towards the apex.

Examination of Catch.

The short zinc cone leading to the wider glass funnel at the end of the net has the effect of concentrating the air flow at this point and most of the insects are swept through and confined, but each individual is not necessarily swept through immediately; therefore, when the catch is large and insects are arriving in a constant stream, a number are found congregated in front of the entrance to the funnel.

It has not been found possible to overcome this difficulty at present and the original intention of incorporating a mechanism which would automatically change the container at intervals has not been carried out. Consequently, when the catch has to be examined at regular intervals, the nets are removed and replaced by another pair; any insects remaining near the mouth are shaken down and the fabric is folded over the hoop to prevent any escape until the greater part of the net is placed in a killing chamber. After death the contents are emptied down a funnel into a pill box.

Cost of Materials.

The total cost of the materials for the trap, excluding the nets, was approximately £12. The construction was carried out by the authors in the workshop at Rothamsted. Each pair of the nets requires two 22 in. hoops and 5 yards of the fabric known as "book-muslin no. 86." The cost per net is approximately a half-crown.

Examples of Catches made by the Trap.

This paper is intended as a description of a new weapon for the study of insect activity rather than as an account of the results obtained with it, but some of the catches are given here as an indication of the kind of material which is collected.

The trap in its present form, but with the nets at the same level, was set up on 1st February 1935 on a plot of rough grass at Rothamsted lying close by the experimental orchard and surrounded by grass land on the other sides. The centre of each net was 2 ft. above the ground.

The current was switched on at 16.30 G.M.T. on 2nd February and was left on until 10.00 on 3rd February, when the nets were removed and the catch examined. Thirty insects were found, as set out in Table I. A further run during the daylight hours of 3rd February produced a catch of 369 insects: 362 small Diptera, 5 Coleoptera and 2 Psyllids. The catch during the night of February 3rd-4th (16.30 to 10.00) was rather higher, with 54 insects, than that of the previous night. The maximum temperature during the days, minimum temperature during the nights, together with the relative humidity and a general description of the weather conditions are given in the table.

TABLE I.
Analysis of catches during a period of three nights and two days.

FEBRUARY 1935.

Date ...	...	2nd-3rd	3rd	3rd-4th	4th	4th-5th
Time ...	...	16.30-10.00	11.00-15.30	16.30-10.00	11.00-15.30	16.30-10.00
HOMOPTERA						
Psyllidae	...	—	2	—	—	—
COLEOPTERA	...	—	5	—	48	—
DIPTERA						
Chironomidae	...	21	239	34	2,344	29
Trichoceridae	...	1	5	14	7	33
Cecidomyiidae	...	1	22	—	168	—
Mycetophilidae	...	3	17	1	211	65
Psychodidae	...	—	5	5	32	3
Acalypterae	...	4	74	—	163	1
		30	369	54	2,973	131
Max. day temperature	...		50.2°F.		47.3°F.	
Min. night temperature		41.4°F		37.6°F.		43.1°F.
Relative humidity (at 9.00 hrs.)	...		81%		92%	
General weather conditions		Cloudy, moderate N.W. wind	Overcast, showers, light wind	Overcast, slight rain light wind	Fair, periods of sunshine	Fair, sky variable, light N. wind

The next day was fair, and very humid, with periods of sunshine, and the catch went up to 2,973 insects, of which 2,344 were small Chironomids of the genus *Smithia*. The insect activity fell during the following night, but was still greater than on the two previous nights.

On 14th February one net was placed 22 in. lower than the other, as described above, the height of the centres of the nets being 15 in. and 37 in. respectively from the ground. For the next fortnight bad weather prevailed and the catches were very small. Then at the beginning of March, water got into the lower fan motor and caused the windings to be burnt out. While repairs were being made, the brass cowls for the protection of the spindles were designed and fitted, and they have proved entirely successful in preventing a recurrence of the trouble.

Trapping was resumed on 13th March; each 24 hours was divided into three periods of 3 hours and one of 15 and the nets were changed at the beginning of each period. The times were 9.15 to 12.15, 12.15 to 15.15, 15.15 to 18.15, and 18.15 to 9.15, the beginning of the last period being approximately sunset at that season.

An example of a complete day's catch, from 9.15 on 20th March to 9.15 on 21st March is given in Table II. The day was remarkable for the sudden increase in the numbers of small Staphylinid beetles and for the fact that 78 per cent. of these were found in the upper net. A similar increase in the number of STAPHYLINIDAE with height above the ground was very evident during the days preceding and succeeding 20th March, though the numbers involved were smaller.

TABLE II.

Analysis of catches during a period of 24 hours continuous running.

20th-21st MARCH, 1935.

Time				9.15-12.15		12.15-15.15		15.15-18.15		18.15-9.15	
				U.	L.	U.	L.	U.	L.	U.	L.
HOMOPTERA											
Psyllidae	...	...	...	1	—	—	3	—	—	—	—
COLEOPTERA											
Staphylinidae	...	...	...	105	38	129	39	290	73	11	—
Other Coleoptera	...	...	...	15	17	46	45	48	51	2	5
MICROLEPIDOPTERA				—	—	—	—	—	—	1	—
DIPTERA											
Chironomidae	...	...	...	14	31	19	27	38	58	54	61
Trichoceridae	...	...	...	1	—	—	—	—	1	2	5
Cecidomyiidae	...	...	...	8	10	5	13	5	13	—	3
Mycetophilidae	...	...	...	28	19	61	33	70	43	4	4
Psychodidae	...	...	...	—	—	—	—	31	124	20	44
Lonchopteridae	...	...	...	—	—	—	1	—	—	—	1
Acalypterae	...	...	...	11	16	17	23	9	8	2	3
HYMENOPTERA											
Chalcidoidea	...	...	...	—	4	7	14	3	3	—	—
Ichneumonoidea	...	...	...	2	2	1	2	—	—	—	—
SPIDERS				2	—	—	—	—	—	—	—
				186	137	285	200	494	374	96	126
				1,898							

Maximum day temperature 63.2°F.

Minimum night temperature 34.5°F.

Relative humidity (at 9.00 hrs. on 20th) 85 per cent.

Relative humidity (at 9.00 hrs. on 21st) 79 per cent.

Slight mist early morning followed by bright sunshine during day; clear sky at night; calm.

U=upper net. L=lower net.

Apart from these insects, and considering the latter part of March as a whole, there appears to have been a progressive increase in the catch of the upper net, relative to that of the lower one, during the daylight hours, and a sharp decrease during the hours of darkness.

These two series of catches show how the mechanical trap can be used as a means of sampling the flying insect population of a given area and how, by changing the nets at intervals, the variation in numbers with time and season can be investigated.



Fig. 1. Mechanical insect trap driven by water-power.



Fig. 2. Water-wheel and net of mechanical insect trap.

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A WATER-POWER MECHANICAL INSECT TRAP.

By W. MALDWYN DAVIES, B.Sc., Ph.D.,

University College of North Wales, Bangor.

(PLATE XXII.)

During investigations on the ecology of Aphids infesting the potato crop it became necessary to study the precise effect of the different meteorological factors upon migration. Traps, treated with adhesive material, which depended on a wind-vane to keep them at right angles to the direction of migration were first used but proved unreliable, since it was found that aphid migration attains a maximum when there is little or no wind. Kites, also, proved impracticable for the same reason. It was, therefore, essential to construct a trap which worked independently of meteorological conditions. I am indebted to Dr. C. B. Williams and Mr. P. S. Milne, of Rothamsted Experimental Station, for the opportunity of discussing and examining the construction of their electrical mechanical trap, described in the preceding paper, which formed the basis of one constructed at the College Farm, Aber, near Bangor. Since, however, the village of Aber has no electricity supply it was necessary to alter, materially, the mode of construction in order to drive the trap by water-power. For this reason and, since the modified form can be used in districts where there is no electricity supply, it was suggested that the present account of the *water-power* mechanical insect trap should be published along with the description of the Williams and Milne trap. I am, therefore, grateful to the authors of the preceding paper for the opportunity of seeing their manuscript, thus avoiding, by reference, repetition of the description of several parts.

Mechanical Description.

The Frame.

It will be seen from Plate XXII, fig. 1 that the horizontal framework—including the radiating steel tubing and the mode of attachment (fig. 1, A), guy-wires and wire-taunts, the wooden hoops (23 in. diameter), and the net material (45 meshes to the inch), are precisely as described in the preceding paper. In the present trap, however, the entire framework, including the vertical central tubing (8 ft. 8 in.) to which the guy wires are attached at the top, has to rotate. This was made possible (see text-fig. 1) by using an old bicycle steering-column (BY) and inserting the vertical central tubing (V) of the trap in lieu of the handle-bars. The trap thus revolves smoothly on ball-bearings (BL). A solid iron tube carrying the double ash-pulley (PL) is inserted into the lower part of the steering column from below. The upper pulley has an external diameter of 8 in. and an internal groove diameter of 6 in. The groove of the lower pulley is 5 in. diameter and was added simply to give a choice of pulleys if desired. The pulleys were turned out of a block of seasoned ash since it was thought that the driving-rope would be less liable to slip on a wooden pulley. With the use of a wire-rope there is no reason why the pulley should not be metallic.

The Nets.

The wooden hoops forming the mouth of the nets are attached, one at each end of the medium-sized arms (5 ft. 6 in.) of the horizontal framework, by bolts through the arm and also through the ends of the Y-shaped central supports in the mouth

of the nets. The net is made of book-muslin (No. 86) and is strengthened at the mouth by 2 in. chair-webbing, which is fastened to the wooden hoops by long drawing-pins (Plate XXII, fig. 2). The nets, in the present trap, are 6 ft. long and at the apex are strengthened by a band of unbleached calico, which is fastened round

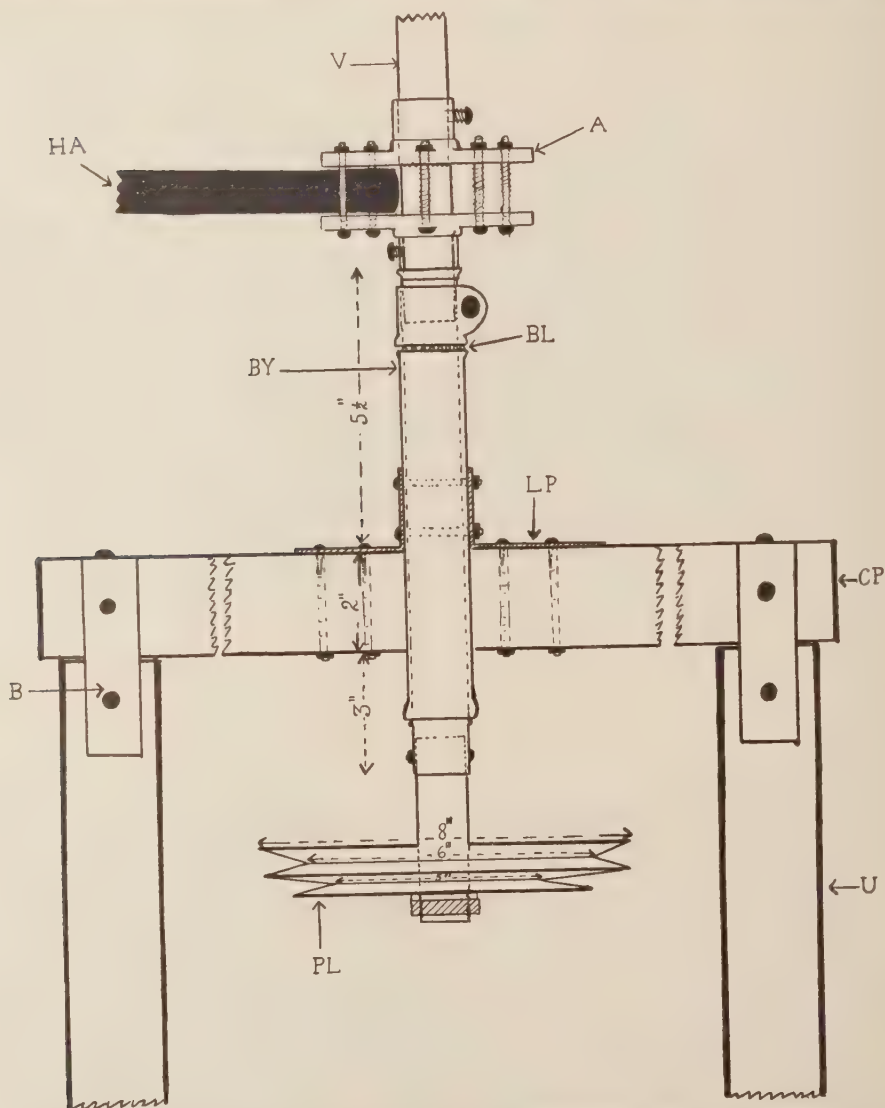


Fig. 1. Section of rotating column and supports of mechanical trap: *v*, vertical central tubing; *a*, attachment of the arms; *by*, bicycle steering column; *lp*, L-shaped plates; *cp*, cross-piece of supports; *u*, uprights of supports; *pl*, ash pulley; *b*, iron bands; *bl*, ball-bearings; *ha*, horizontal arms.

a circular galvanised trap-carrier (text fig. 2, TC) by cord and thick rubber bands (B). The galvanised trap-carriers, which are suspended from ends of the long arms (A., 8 ft. long) by a wing-screw, are constructed on the "lobster-pot" principle with an inner cone (L) which prevents the insects from returning to the net (N) when

once they have passed into the cylindrical trap. The trap consists of a circular celluloid cylinder (C) 2 in. in diameter which fits tightly over the galvanised carrier and at the apex is closed with fine muslin (M). The catch can then be easily collected by removing and corking the celluloid cylinder and replacing it with another empty celluloid cylinder. Any insects which have not passed into the cylinder can be readily blown in through the sides of the net when the catch is taken.

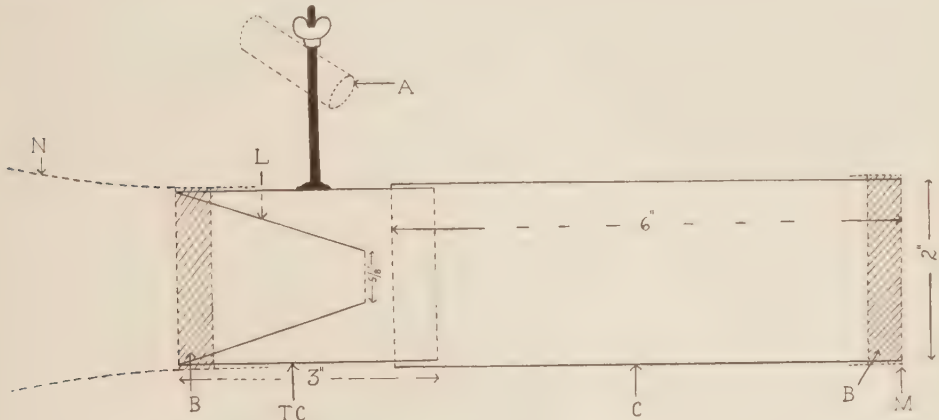


Fig. 2. Section of the apex of the net showing trap: *a*, end of long arm; *n*, net; *l*, "lobster pot" cone; *b*, rubber bands; *tc*, galvanised trap-carrier; *c*, celluloid cylinder; *m*, muslin.

The Supports.

Since the vertical central tubing (V) of the framework rotated, it was necessary to clamp the framework *above* the ground. A wooden support (Plate XXII and text-fig. 1) was erected, consisting of two upright posts (U), 6 ft. \times 4 in. \times 2 in., driven into the ground until 3 ft. 8 in. remain above. A cross-piece (CP) of similar timber (3 ft. 6 in. in length) is firmly bolted on the tops of the uprights by two iron bands (b). The bicycle steering column then passes through a hole in the centre of the cross-piece and is gripped firmly on either side by two iron L-shaped plates (LP), which are drawn together round the sides of the steering-column by tightening the four bolts passing through the plates. In this way the steering-column is securely held while the pulleys (below), the horizontal arms (HA) and their attachment (A), together with the vertical tubing suspending the guy-wires (above), rotate freely.

The cross-piece of the supports, also, has suspended from it (see Plate XXII, fig. 1) a rectangular iron frame carrying two small pulleys (2 in. diameter) over which the driving-wire passes.

The Driving-wire.

Some difficulty was experienced in getting the best form of driving belt. Leather was unsuitable, owing to the effect of variable weather conditions upon it. For the same reason, best quality treated rope (as used by sail-makers), which worked admirably at first, proved useless. Rubber-tying, with steel spiral centre, worked well for a short period, but the steel spiral soon broke owing to passage over the small pulley. Finally, flexible steel wire of $\frac{1}{8}$ in. diameter (as used by builders for lashing scaffolds) proved excellent material for a driving belt. It is cheap and has worked smoothly for over two months without any alteration. The length of the wire in the present instance is 28 ft., giving a driving distance of 14 ft. The wire passes under an adjustable pulley (Plate XXII) fastened on a small stake in front

of the supports ; this permits the necessary adjustment of tension of the rope when desired.

The Water-wheel.

The water-wheel (Plate XXII, fig. 2 and text-fig. 3) consists of two circular galvanised iron sheets (24 in. diameter) which are held 7 in. apart by an inner circle of galvanised sheeting (IC) soldered at a radius of 7 in. from the centre. The paddles (P) of the wheel, which serve to hold the water, are made by soldering curved galvanised partitions at intervals of 7 in. around the wheel. Each compartment forms a square (7 in. \times 7 in.) at the top and the partitions curve so that the base of the cup is 7 in. \times 4 in. (text-fig. 3). Approximately two quarts of water is held by each cup before it overflows.

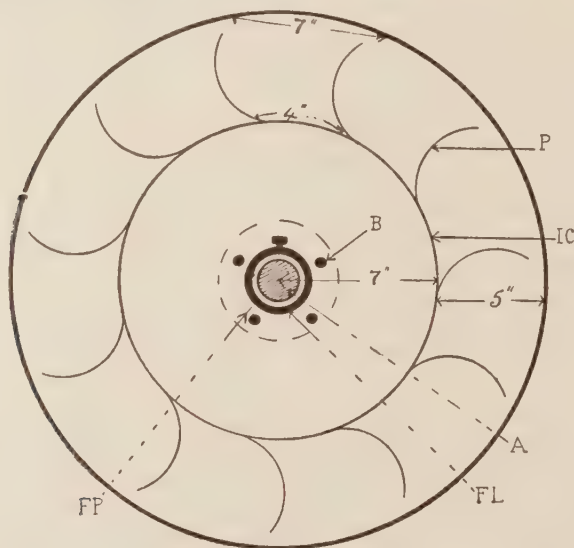


Fig. 3. Section of water-wheel: *p*, paddle; *ic*, inner circle; *a*, axle; *fp*, face-plate; *fl*, flange of face-plate; *b*, bolt.

Through the centre of the wheel there passes an iron axle (A), 24 in. long, 2 in. diameter ; this is carried through the centre of the wheel by two circular face-plates (FP), one each side of the wheel. The axle rests (Plate XXII, fig. 2) in a set of brass bearings ("plummers blocks"), each bolted into a supporting wooden post (8 in. \times 4 in.) driven into the ground at a distance of 12 in. apart. The bearings are oiled when necessary with a heavy oil. A steel driving pulley, 6 in. external diameter and with 3 in. internal groove diameter, is attached to one end of the axle ; the groove is acutely V-shaped and grips the driving wire as it passes around it (Plate XXII, fig. 2).

The Water Supply.

The water supply is obtained from a small stream by sinking, in the bed of the stream, a T-shaped joint portion of an ordinary cast-iron rain-gutter (as used on houses) and constructing a small dam around it with stones and clay. In this way the water is collected and directed into the spout entrance. A series of lengths of 2-in. piping leads from the spout and conducts the water above the water-wheel and, terminating in a bent portion, directs the water into the compartments of the wheel (see Plate XXII, fig. 1). A very small stream will suffice to drive the wheel since all that is necessary is to have sufficient water so that when the small dam is constructed the water will fill the mouth of the 2-in. pipe. It should be appreciated

that a great fall of water is not required, since it is largely the weight of the water in two or three compartments that drives the wheel. Thus, with sufficient flow to keep the two or three compartments at the top of the wheel more or less continually full there is enough driving force to propel the trap even in winds up to 25-30 m.p.h.

Rate of Rotation.

When there is no wind, or when the wind velocity is below 5 m.p.h. the trap rotates smoothly at the rate of 5 revolutions a minute. Since the main object of this trap was to study migration of Aphids, which do not migrate during high winds, the trap runs perfectly for these observations. During winds of 10-15 m.p.h. there is only a slight variation in the speed and the trap has worked in gusty weather ranging up to 30 m.p.h., though at the peak of the wind velocity it may remain stationary with one net exposed to the wind for a few seconds. Since, however, both nets in this trap are at the same level and since either trap stands equal chances of a momentary halt when facing the more severe gusts, the effect on the aggregate catch is evened out.

Insects caught.

As stated, the trap was primarily constructed to catch migrating Aphids and for this purpose it has proved highly satisfactory. Continuous observation has revealed no evidence that Aphids escape through the open mouth of these nets. In fact, it was originally intended to devise some mechanism for closing the mouth of the net but such was found unnecessary. Most of the Aphids are carried to the far end of the net as the trap moves forward and they readily pass through the galvanised trap-carrier into the celluloid cylinder. Others, which settle on the sides of the net, are carried to the apex as soon as they again take to the wing or tend, by the shaking of the muslin sides of the net, to pass to the apex. Once inside the celluloid cylinder they congregate towards the light and make no attempt to pass back through the galvanised carrier. The aphid migration in North Wales this season (since 1st June when the trap was erected) has not been so intense as during the last two years when "clouds" of migrating Aphids were not uncommon. However, during the few migrating periods this year it was evident that the trap was reliable in its recording of the catch. For instance, on 25th June 445 Aphids were caught in the nets between the hours of 9.00 and 21.00 G.M.T. and there was by no means much visible evidence of aphid migration on that date. The total catch of insects on that date, from 9.00 of the 25th to 9.00 of the 26th, numbered 776 comprising mainly small Diptera of the families CHIRONOMIDAE, MYCETOPHILIDAE, CECIDOMYIDAE and CULICIDAE. Among the 60 Coleoptera caught 31 were STAPHYLINIDAE. There were 46 Hymenopterous parasites (unnamed but of *Aphidius* type) and it has been interesting to note that the high degree of parasitism that has been observed among Aphids in July was accompanied by appreciable increases in the numbers of parasites caught in the trap. It should be emphasised that the trap is erected in an open field (Plate XXII, fig. 1) which, though not frequented by the large numbers of insects found in enclosed areas, is typical of the conditions under which migration occurs on the average farm in North Wales.

Cost of Material.

The total cost of materials for the insect trap, including the water-wheel but not the 2-in. cast-iron pipes, was approximately £5; the main items of cost being the castings, galvanised sheeting and the iron tubing. The construction of the water-wheel may involve appreciable labour charges, but any skilled smith should be able to do the necessary soldering without incurring much expense.

The writer wishes to acknowledge the valuable help of Mr. T. R. Jacobs, of the Chemistry Department of this College, who assisted in the construction of the trap.

THE BACTERICIDAL PROPERTIES OF EXCRETIONS OF THE MAGGOT OF *LUCILIA SERICATA*.

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With a few notable exceptions, insect excretions are regarded as waste material. The excretions of the blowfly maggot, *Lucilia sericata*, Meig., however, have been found to possess certain potential therapeutic properties.

Aqueous solutions of these maggot excretions contain a potent bactericide, (Simmons 1935), capable of killing certain pathogenic bacteria. There is reason to believe that this phenomenon is not confined to blowfly maggots. Duncan (1926) found that the dissected gut contents of several species of adult insects and arachnids were lethal to certain organisms. Graham-Smith (1914), Nicholls (1912), Manson-Bahr (1920), and Wollman (1921), noticed that specific organisms eaten by flies could not be recovered in a viable state after an interval of a few hours to a few days. The longer lapse of time would allow the organisms to be passed out in the faeces, and this was, in some cases, shown to happen. Duncan, however, found the faeces of several insects to be sterile, showing that the organisms had been killed in the alimentary tract and were not eliminated in this instance by being passed out in the faeces. There are records of other similar observations, and probably the excretions from various insects would show bactericidal action if tested.

Investigations on the destruction of bacteria in the intestines of insects seem to have been made chiefly on blood or flesh feeders. A study of the fate of various pathogenic bacteria and fungi of plants when exposed to the excretions of phytophagous insects or eaten by them would be of much interest.

The author is not aware of any previous work on the bactericidal action of the excretions of blowfly maggots. Livingston & Prince (1932) claimed to have demonstrated such action with an extract derived from macerated surgical maggots, a material entirely different from that used in the present investigation, but later workers (Maseritz, 1934; Robinson & Norwood, 1933; Slocum *et al.*, 1933) were unable to confirm their findings. The utilisation of entomologically produced bactericides therefore appears to be new.

The maggots used in this investigation were those of *Lucilia sericata*. The bacteria were exposed to the excretions at a temperature of 37 C. unless otherwise stated.

Methods for Procuring the Bactericide.

A large number of non-sterile blowfly eggs were placed on a small amount of raw beef. After about 3 days the resulting maggots had consumed most of the food and were thus readily removed. To obtain the excretions the maggots were then raked from the food residue with a spatula into a fine-mesh wire sieve fitted into a glass funnel over a collecting flask. Wire gauze was fastened over the top of the sieve with a tight-fitting metal collar. Distilled water was occasionally sprayed through the top with an atomizer, which seemed to cause the maggots to excrete more freely. They were usually allowed to excrete over a period of 2 to 4 hours. The number of maggots varied, as did also the amount of water applied. The

quantity of material collected was approximately the same as the quantity of water used; it is evident, therefore, that no standard concentration was obtained. The excretions were removed from the flask and autoclaved at 10 pounds' pressure for 20 minutes and then cultured for sterility and placed in the refrigerator at 6°C., to be used, generally the following day.

Test for Bactericidal Action.

*Organisms used.**—The following species of bacteria were used in these tests: (1) *Staphylococcus aureus*, an organism frequently the cause of abscesses, septicaemia, and osteomyelitis. The strain used was a standard one employed by the United States Food and Drug Administration for the testing of disinfectants (Ruehle & Brewer, 1931). (2) *Streptococcus pyogenes haemolyticus*, two strains isolated from empyema and a throat infection. (3) *Streptococcus faecalis*, from faeces. (4) *Streptococcus mitior*, from fluid aspirated from a knee infection. (5) *Clostridium welchii*, isolated from a fatal case of gas gangrene following a compound fracture of the leg. (6) *Proteus vulgaris*, obtained from the Bacteriological Department of the Army Medical School. (7) The typhoid bacillus, *Eberthella typhi*, a standard strain employed by the Food and Drug Administration for the testing of disinfectants.

Technique employed.—Initial tests were conducted with *Staphylococcus aureus* and *Streptococcus pyogenes*. The organisms were removed from agar slants and suspended in physiological saline, after which 1 cc. of the dense suspension was placed in 9 cc. of the excretions, and another 1 cc. in 9 cc. of saline as a control. From these suspensions 1-100 and 1-1,000 dilutions were also made. During incubation 1 cc. of fluid from each tube was plated at intervals of from 5 minutes to 4 hours.

All the remaining tests, except those on *Clostridium welchii*, consisted mainly in exposing 0.1 cc., containing approximately 50,000,000 organisms, of a 24-hour broth culture to 5 cc. of the excretions and culturing this for sterility at intervals by broth inoculations, and in some instances also by plate cultures. Dextrose broth neutralized with NaHCO_3 was used for the streptococci cultures. The tests with *Cl. welchii* were made by exposing 1 cc. of the broth from Robertson's chopped-meat media, which supported a dense 24-hour growth of the organism, to 5 cc. of excretions, and inoculating 0.1 cc. of this back into Robertson's media at various intervals. After 24 hours' incubation the latter was re-checked for sterility by inoculation into litmus milk. Saline checks were run with this and all other tests conducted.

Results.—The results are summarised in Table I. In the tests with *Staphylococcus aureus* different results were obtained with the broth and wash cultures, and this is shown in the table.

One test was conducted as previously described except that 250,000,000 organisms of the standard *S. aureus* were used, and the results were the same as those obtained with broth cultures of 50,000,000.

In addition to these tests, an experiment was conducted with a sample of excretions that had been desiccated under reduced pressure at 60°C. Thirty cubic centimetres of water (the amount of liquid originally present) was added to the dry material and the mixture autoclaved at 10 pounds' pressure for 20 minutes. A large part of the dry matter failed to go back into solution. The colour of the supernatant liquid was dark green and, unlike the fresh material, was transparent. A light saline suspension of the standard *S. aureus* was added to 4.5 cc. of the liquid,

* Most of the organisms used and the information concerning them were obtained through the courtesy of Major H. R. Livesay, of the Bacteriological Department of the Army Medical School, Washington, D.C.

and 1 cc. portions of this plated after 10 minutes' exposure showed no growth, while the controls were positive. The one test shows at least that the active principle can be obtained in a dry state, and this may prove to be the most practical way of obtaining it.

Several tests were conducted with excretions from maggots that had been reared aseptically as for surgical use (Robinson, 1934; Simmons, 1934, 1935). The technique of collecting the material was essentially the same as that previously described except for modifications to maintain sterility. This material always showed definite bactericidal action on *Staphylococcus aureus*, but did not appear to be so potent as that collected from specimens reared on decayed beef. As no standard concentration was used, its apparent weaker action may have been due to extreme dilution, or, on the other hand, to the type of food on which the maggots fed.

TABLE I.

Lethal Action of heat-sterilised Maggot Excretions upon various Bacteria.

Organism	Minutes' exposure							
	5	10	15	30	60	120	180	240
<i>S. aureus</i> :								
Wash cultures ...	—	—	—	—	—	—	—	
Broth cultures ...	+		±*		—	—		
<i>St. pyogenes</i> ...	—	—	—	—	—	—	—	—
<i>St. faecalis</i> ...	+		—		—	—		
<i>St. mitior</i> ...	+		—		—	—		
<i>Cl. welchii</i> ...	—	—		—	—	—	—	—
<i>P. vulgaris</i> ...	—	—	—	—	—	—	—	—
<i>E. typhi</i> ...	+		—		—			
Saline controls ...	+	+	+	+	+	+	+	+
+ Heavy growth. ± Light growth. — Negative.								

* Plate cultures of this material failed to show any growth, indicating that the number of organisms present was exceedingly small.

One test was conducted with the heat-sterilized excretions on *S. aureus* at 20°C. Complete kill was not evident after 2 hours' exposure, although only a very light growth could be obtained. This slowing up of activity with decrease in temperature resembles that occurring among most well-known disinfectants.

Discussion.

From the results obtained it is evident that a powerful bactericide is contained in the excretions of the blowfly maggot, *Lucilia sericata*. Its lethal action against the important causative organisms of pyogenic infections tends to explain the remarkable decrease in the number of bacteria in wounds under maggot treatment, and is no doubt a factor in the success obtained with such therapy.

The production of a heat-stable bactericide by a living organism is a peculiar phenomenon, and much work remains to be done on the problem. The active principle

in maggot excretions is evidently of a non-viable nature, as is indicated by its resistance to heat (110°C. for 20 minutes). It probably bears no relation to a bacteriophage or bactericidal enzyme. It is evidently not a lysozyme, as a sample of excretions inoculated with *Streptococcus pyogenes*, and from which no growth could be obtained, showed after 2 days' exposure numerous dead bacteria. Further evidence that it is not a lytic agent is borne out by the recent work of Stewart (1935), who sectioned and stained portions of the alimentary canal of maggots from which no growth could be obtained and found numerous dead organisms. Duncan (1926) also found that the gut contents of certain insects were devoid of phage or lytic material, although possessing bactericidal qualities.

The potency of the material was found to diminish gradually on standing in aqueous solution, although a week-old sample of dried excreta seemed to be still potent. Duncan found that the dissected gut contents of the tick, *Argas persicus*, Fischer, when dried, maintained their bactericidal action undiminished for at least six months.

The bactericide does not appear to be so readily inactivated by the addition of organic material as would be expected with ordinary disinfectants. Its action in infected wounds indicates this to be true or that it is supplied in sufficient quantities to overcome this obstacle.

There are indications that maggot excretions are relatively non-toxic and non-irritating and probably could be used in infections inaccessible to living maggots.

One wonders what rôle such a substance could play in the life of the maggot. Could its immunity to the many organisms in its environment be explained on this basis? If the substance is produced by certain glands, the problem should prove of interest to insect morphologists in tracing down such organs. On the other hand, it may be that no particular organ is alone responsible, but that the active principle is due to a combination of various so-called "waste" products.

Duncan's work (1926) indicates that the bactericidal substance in the alimentary canal of insects acts differently on different bacteria. For example, he was able to demonstrate that the gut contents of *Stomoxys calcitrans*, L., actually enriched the growth of *Bacillus pestis*, while it had a lethal action on *Bacillus subtilis*. On the other hand, he showed that the gut contents of different insects acted differently on the same organism. Could it be that certain disease organisms are carried by only specific insects because the bactericides of other insects are lethal to the particular organism? An investigation of this problem would be of interest.

Summary.

The excretions of the blowfly maggot, *Lucilia sericata*, have been found to contain a potent bactericide, and the technique for the collection of this material is given. There is evidence that other insects besides the one investigated may also produce this substance.

The active principle is not destroyed by autoclaving at 10 pounds' pressure for 20 minutes and desiccation does not inactivate it.

The bactericidal action of the substance was demonstrated by tests on seven species of bacteria, most of which are of aetiological importance in osteomyelitis and other suppurative infections. The lethal action against such organisms seems to be an important factor in the good results obtained with maggot therapy.

The work seems to open a field in which interesting investigations could be conducted with possibilities of producing other new and useful disinfectants from living organisms.

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NEW INJURIOUS CURCULIONIDAE (COL.) FROM MALAYA.

By Sir GUY A. K. MARSHALL. 27

Subfamily BRACHYDERINAE.

Dermatodes cinchonae, sp. n.

♂♀. Derm black or piceous, with uniform dense brown scaling above, becoming paler laterally and beneath.

Head only shallowly impressed behind the eyes, the forehead flat with dense recumbent scales and very short inconspicuous subrecumbent setae, the median sulcus very narrow. *Rostrum* a little longer than broad, widening from base to apex; the disk almost flat, the sculpture being entirely concealed by the dense scaling; the epistome elevated and bearing a lunate impression. *Antennae* with the two basal joints of the funicle equal, 3 a little longer than 4, 4-7 subequal in length and about as long as broad, 7 subconical and with its apex slightly produced externally. *Prothorax* slightly transverse (♂ 4.5:5, ♀ 4:5), rounded laterally, broadest at a little beyond the middle, truncate at the apex dorsally; the dorsum rugulose, with shiny granules along the middle of the disk only, the lateral granules being covered with scaling, and without any median furrow. *Elytra* ovate, with the shoulders rounded, and acuminate at the apex; the dorsal outline rising from the base, then flattened to the top of the declivity, then sloping steeply behind, and finally becoming perpendicular near the apex; the large punctures in the striae completely hidden by scaling; the alternate dorsal intervals strongly raised, intervals 2 and 4 with a series of large shallow depressions, which are more marked in ♂ than in ♀; interval 1 without shiny granules, 3 with a few very small ones on the basal half, 5 with a complete row of very small granules, and the other external intervals with a complete row of larger granules; the setae small and narrowly oblong. *Legs* with the tibiae rather slender, the anterior pairs distinctly curved, the hind pair of ♂ with a row of small sharp teeth and smaller ones in ♀.

Length 4.0-5.2 mm., *breadth* 1.7-2.5 mm.

JAVA: Tjinjirocan, 3♂♂, 1♀, on cinchona, ii.1934 (*R. Awibowo*).

Nearly allied to *D. elevatus*, Pasc. 1885, which is a larger insect, with a distinct median furrow on the pronotum; the eyes are somewhat less convex, and joint 7 of the funicle much longer than broad; the setae on the elytra are much larger, lanceolate, and suberect on the declivity; the front tibiae not curved on the outer edge.

D. camphorae, Mshl. 1929, is also very similar, but has the pronotum much less rugulose and without any shiny granules; the elytra are narrower at the shoulders and have no dorsal granules.

Subfamily EREMNINAE.

Corigetus albizziae, sp. n.

♂♀. Derm black, rather unevenly clothed with pale metallic green scales, more or less suffused with whitish powder; the prothorax with a broad dark stripe on each side in which the green scales are much smaller and more sparse; similar very indefinite darker patches on the elytra, especially on intervals 4 and 5; underside with round metallic green scales laterally and a broad stripe of narrow grey scales down the middle of the venter.

Head with dense green scaling and short suberect spatulate white setae; the forehead about as broad as an eye, depressed, with a very fine median carina from the fovea on to the base of the rostrum; the eyes not very convex, deepest a little behind the middle. *Rostrum* about as long as its apical width, parallel-sided in the basal half and broadly dilated anteriorly; the dorso-lateral carinae prominent, the median area between them comparatively narrow, deeply depressed in front and containing a low median carina (often concealed by scaling) on the basal half only; just outside the dorso-lateral carinae a broad short sulcus, and immediately below this a broad carina running forwards from the middle of the eye, then curving strongly inwards to form the posterior margin of the scrobe; the epistome forming a raised acute angle behind; the lower surface obtusely elevated in the middle, so that when the rostrum is viewed laterally there is a deep incision at the base; mentum with two setae. *Antennae* with the scape strongly curved, stout, gradually widening from base to apex, carinulate, with short broad suberect brown setae and sparse green scales; the funicle with joints 1 and 2 equal, 3 and 7 subequal, 4-6 slightly shorter and subequal. *Prothorax* almost parallel-sided from the base to beyond the middle, then distinctly narrowed to the apex without any apical constriction; the basal margin deeply bisinuate, the median lobe being broadly rounded; the apex truncate dorsally, the postocular lobes obsolescent but with distinct vibrissae; the dorsum with the rather coarse punctures concealed by scaling and with a very shallow rounded impression on each side near the base. *Scutellum* subquadrate, squamose. *Elytra* narrower and subparallel-sided in ♂, wider and slightly dilated behind in ♀; the striae broad, with rather large deep punctures (hidden by scaling), the intervals when abraded exhibiting minute scattered granules and bearing irregularly duplicated rows of short scale-like subrecumbent whitish setae. *Legs* with a small sharp tooth on the femora; the anterior pairs of tibiae with an obtuse angulation (more marked in ♂) above the middle on the lower edge, the median tibiae of ♂ shallowly sinuate dorsally.

Length 5.0-6.1 mm., *breadth* 2.0-2.5 mm.

SUMATRA: Pematang Siantar, East Coast, 1,500 ft., 2♂♂, 2♀♀, on *Albizzia moluccana*, xii.1931 (*R. I. Nel*-type); Oeloe, East Coast, 1♀, on tea, ii.1934; Sibolangit, 1♂, 1♀, viii.1924; Brastagi, 1♀, viii.1924.

Closely resembling *C. saturatevirens*, Boh., but the latter species differs *inter alia* in having joint 2 of the funicle longer than 1 and a single row of fine erect setae on the elytral intervals, the anterior tibiae are not angulated, and there is no elevation on the lower surface of the rostrum.

***Corigetus corbetti*, sp. n.**

♂♀. Derm black, with pale metallic green scaling; prothorax normally with a broad black stripe on each side, but these are sometimes more or less invaded by green scales; elytra variegated with irregular black patches; underside with grey scales in the middle and green ones laterally.

Head with dense green scaling and suberect spatulate pale setae; the forehead broader than an eye, shallowly depressed, with a median carina continuous with that on the rostrum; eyes moderately prominent, deepest behind the middle. *Rostrum* scarcely as long as its apical width, gradually narrowing from the base to the antennae and broadly dilated apically; the dorso-lateral carinae obtuse, the median area rather deeply impressed, with a fine median carina, and terminated in front by a transverse ridge at some distance behind the epistome; outside the dorso-lateral carinae a strong oblique carina, forming the posterior margin of the scrobe but not reaching the eye; the epistome forming a sharp right angle behind, the space between it and the transverse ridge, deeply impressed, bare, and divided by a short median carina; the underside with an obtuse median elevation and a deep rounded fovea immediately behind it; mentum with two setae. *Antennae* as

in *C. albizziae*, sp. n. *Prothorax* with the sides gently rounded beyond the middle, broadest at the base, sinuate laterally in the basal half, with basal angles acute, and the apical margin strongly arcuate dorsally, the postocular lobes obsolescent and with a few vibrissae; the dorsum very coarsely punctate, with a broad saddle-like depression occupying most of the basal half and a shallow transverse impression near the apex; the stout setae short and suberect in ♂, much longer and more erect on the disk in ♀. *Scutellum* round, with sparse narrow scales. *Elytra* broader in ♀, but widest behind the middle in both sexes, sloping from the basal angles to the prominent shoulders, separately rounded at the apex; the shallow striae with large close punctures which are partly covered by, but visible through, the green scaling; the intervals smooth, with irregularly duplicated rows of short spatulate suberect setae. *Legs* with a small sharp tooth on the femora; the anterior pairs of tibiae not angulate on the lower edge, and the median pair not sinuate dorsally.

Length 3.3–4.5 mm., *breadth* 1.3–1.9 mm.

MALAY PENINSULA: Serdang, 2♂♂, on *Manihot utilissima*, vii.1924, 1♂, 1♀, x.1924 (G. H. Corbett & B. A. R. Gater); Kuala Lumpur, 1♂, on *Mallotus* sp., vi.1925, 1♂, 1♀, on *Derris*, xi.1927, 3♂♂, 2♀♀, on *Cinnamomum zeylanicum*, ix.1928, 2♀♀, on flowers of *Hibiscus esculentus*, i.1929, 1♀, on cinnamon, v.1932 (G. H. Corbett); Serdang, 1♀, on *Derris elliptica*, iii.1932 (N. C. E. Miller), 2♀♀, on *Derris*, iv.1935; Khumpur, 2♂♂, 3♀♀, on *Derris malaccensis*, x.1933 (type); Singapore, 1♀; Kuala Lumpur, 1♂, 2♀♀, vi–vii.1921, 1♂, iii.1931 (H. M. Pendlebury); Kedah, nr. Jitra, 4♂♂, 1♀, iv.1928 (Pendlebury).

Allied to "*Mylocerus*" *scapularis*, Roel., from Sumatra, which must be transferred to the genus *Corigetis* and superficially much resembles the present species, but differing as follows:—The apex of the rostrum is more dilated, being there nearly as wide as the head across the eyes; the antennal scape is much broader and shallowly sulcate dorsally; the pronotum lacks the saddle-like depression, and the discal setae are not erect; the setae on the elytra are much longer, more slender, erect, and arranged in single rows on the intervals.

Subfamily RHYNCHAENINAE.

Rhynchaenus flavirostris, sp. n.

♂♀. Derm rather dull black, with sparse grey and black setiform scales; hind legs piceous brown, the tibiae paler at base and apex; anterior legs entirely pale yellow in ♂ including the coxae, in ♀ brown with the tibiae and tarsi paler honey-brown; rostrum of ♂ entirely pale yellow, that of ♀ brown with the apex paler.

Form broadly ovate. *Head* with the eyes contiguous. *Rostrum* of ♂ a little shorter than the pronotum, stout, slightly curved, not very shiny, with irregular shallow punctures down each side and three short sulci in the basal third, the median one impunctate, and with dense grey scaling at the base only; rostrum of ♀ as long as the pronotum, without any scaling, very shiny, with finer sparser punctures and the basal sulci indistinct. *Antennae* inserted near the base, yellow; the funicle 6-jointed, the joints becoming shorter distally, 5 and 6 transverse. *Prothorax* transverse, widest at the base, strongly narrowed in front, with the sides almost straight, not constricted at the apex, with the basal margin bisinuate and produced in the middle; the dorsum convex on the disk, with strong subreticulate punctures and a broad shallow median furrow from base to apex; the intermingled black and grey setiform scales recumbent and on the lateral margins a few long stiff erect black setae. *Scutellum* with black or grey scales. *Elytra* relatively short and broad (6:5), widest a little behind the shoulders and broadly rounded at the apex; the deep striae with catenulate punctures, the intervals broader than the striae, almost flat, rugulose; the grey setiform scales forming three very indefinite macular bands;

a narrow one at the base, a very broad one about the middle, and a somewhat narrower one near the apex ; near the base of the lateral margin a row of 6-7 erect black setae. *Legs* with the hind femora very large, about three times as broad as the median ones, with two widely separated fine spines on the ventral edges and a few slender erect setae ; the hind tibiae with a curved carina on the outer face.

Length 2.0-2.5 mm., breadth 1.2-1.5 mm.

JAVA : Buitenzorg, 4♂♂, 2♀♀, on leaves of mango, vi.1933 (*Dr. C. Franssen*).

Nearly allied to *Rhynchaenus mangiferae*, Mshl. 1915, of South India and Ceylon, which is, however, smaller and of a yellowish brown colour ; the pronotum is not tumid on the disk and has no median sulcus ; the elytra are narrower with more sloping shoulders, the striae are finer and indistinctly punctate, and the pale setae are longer.

Subfamily NANOPHYINAE.

Nanophyes shoreae, sp. n.

♀. Derm pale flavous ; the head, rostrum, disk of pronotum, and a large triangular patch at the base of the elytra round the scutellum, honey-brown ; the apex of the rostrum, the basal carina of the elytra, the tarsal claws, and the apical fringe of setae on the tibiae, blackish.

Rostrum slightly curved ; that of ♂ a little shorter than the head and pronotum (11 : 12), with two punctate sulci on each side, the outer ones reaching the apex, the inner ones interrupted near the antennae, which are inserted at one-third from the apex ; rostrum of ♀ longer than the head and pronotum (14 : 12), more shiny and much more finely punctate, the inner sulci replaced by a row of fine punctures, the outer sulci much narrower and continued to a little beyond the antennae, which are inserted at the middle. *Antennae* with the scape, funicle and club of the following proportionate lengths, 8 (7 in ♀) : 6.5 : 4.5 ; joint 2 of the funicle unusually long, 2.5 times as long as 1 and equal to 3 + 4 + 5, 3 and 4 equal, 5 a little shorter and subquadrate. *Prothorax* two-thirds as long as the basal width, slightly convex longitudinally, sloping rather steeply in front, and with fine shallow subconfluent punctation, the pale yellowish hairs dense at the sides, but much sparser on the disk, where they are mingled with a few blackish ones, especially towards the base. *Elytra* elongate, widest at the very oblique shoulders and rapidly narrowing from there to the apex ; the fine striae indistinctly punctate, interval 8 with a row of five minute blackish granules at the base between the humeral callus and the basal margin ; the dark scutellar patch extending laterally at the base as far as stria 3, about as long as its basal width, and clothed with black hairs mixed with a few pale ones ; the rest of the elytra clothed with rather dense pale yellowish hairs. *Legs* with one long and two short teeth on the femora, all tipped with black ; the anterior pairs of tibiae distinctly sinuate at the base, these pairs also with a short mucro in the ♂ only ; the front coxae of the ♂ with a stout process at the apex.

Length 3.0-3.5 mm., breadth 1.6-1.9 mm.

MALAY PENINSULA : Singapore, 1♂ (*W. J. Saunders*—type) ; Malacca, 2♂♂, 6♀♀, from seeds of *Shorea curtisii* (*D. B. Arnot*).

This comparatively large species should be easily recognised by its distinctive coloration, the unusually long second joint of the funicle, and by the coxal processes in the ♂.

In forwarding the Malacca specimens, Mr. H. M. Pendlebury, of the Selangor Museum, states that this weevil occasionally causes considerable damage to the seeds of *Shorea*, the timber of which is of value, being used as a local substitute for deal.

Subfamily CEUTHORRHYNCHINAE.

Ceuthorrhynchus oleraceae, sp. n.

♂♀. Derm reddish brown, with the disk of the pronotum, the sides of the elytra and a large common patch behind the scutellum, blackish; rather thinly variegated with narrow whitish, fawn and brown scales, through which the shiny integument is visible, and with an ill-defined short whitish sutural stripe behind the scutellum; underside with uniform whitish grey scaling and a small denser white patch in the upper angle of the mesepimera.

Head convex, rugulose, with subrecumbent scaling, the forehead not broader than the base of the rostrum, less flattened than usual. *Rostrum* short and very stout, as broad as the widest part of the front femora, curved, widened at the apex; in ♂, coarsely punctate and squamose from the base to two thirds, then abruptly becoming bare and impunctate at the apex; in ♀, the punctures becoming gradually finer and sparser beyond the middle. *Antennae* inserted well beyond the middle of the rostrum, testaceous, the scape without any sharp process at the apex; the funicle with the two basal joints subequal in length, the rest becoming shorter distally, but all longer than broad. *Prothorax* strongly transverse (3:2), rather strongly rounded at the sides, widest behind the middle, deeply bisinuate at the base, less deeply constricted than usual at the apex laterally, but the dorsal part of the constriction deep, the apical margin being raised into a sharp ridge, which is more or less crenulated but never sinuate in the middle; the dorsum convex, reticulately punctate, with a small tubercle on each side which does not project laterally when viewed from above, and a deep longitudinal impression in the middle of the base; this impression and the basal angles with broader whitish scales, the remaining scales elongate. *Elytra* a little longer than broad (5:4.5), suboblong, being only a little broader at the shoulders than the prothorax and less narrowed behind than usual, with a triangular flattened area on the basal half of the disk, and sloping rather steeply behind; the striae shallow, each containing a row of whitish recumbent setae; the intervals rather ill-defined, rugulose, the lateral ones bearing small sharp granules towards the apex, which are most evident on intervals 5 and 7 at the top of the declivity; the subrecumbent scales narrow and elongate, except those in the short postscutellar stripe on interval 1 which are somewhat broader; the apices produced into a short separate process in the ♀ only. *Legs* with the femora stout, especially the hind pair, all having a small tooth and a shallow furrow beneath; tibiae straight, gradually widening to the apex; tarsal claws with the basal tooth obsolete.

Length 1.8–2.2 mm., breadth 1.0–1.2 mm.

JAVA: Batavia, 2♂♂, 4♀♀, on leaves of *Portulaca oleracea*, s.1934 (R. Awibowo).

Allied to the Indian *C. portulacae*, Mshl. (Bull. Ent. Res. **6**, 1916, p. 368, f. 2), but smaller and much narrower than that species, which differs also in having a much narrower rostrum, the prothorax less transverse, the elytra with the shoulders much more prominent and lacking the apical projections in the ♀.



TWO CHALCIDOID EGG-PARASITES OF *DIPRION SERTIFER*, GEOFFR.

By CH. FERRIÈRE, D.Sc. &c.

For several years the Farnham House Laboratory of the Imperial Institute of Entomology has been making a study of the parasites of *Diprion* spp., in order to acclimatise the most important of them in Canada. Dr. K. R. S. Morris has been specially engaged on this investigation in Czechoslovakia and Hungary, and this year (1935) has discovered some parasitised eggs of *Diprion sertifer*, Geoffr. Almost at the same time, other eggs of the same host, sent from Sweden, were found to be parasitised by some Chalcids, but belonging to another species. Experiments are actually being made to breed and acclimatise these two species in Canada. Both are Chalcids belonging to the family EULOPHIDAE, sub-family ENTEDONINAE. As very little is known about these egg-parasites of sawflies, we are giving notes and descriptions of these two species, of which one proved to be new.

***Tetracampe diprioni*, sp. n.**

♀♂. Body dark bluish-green, often with some coppery reflections, especially on the scutellum and abdomen. Antennae black. Mandibles yellow. Legs dark brown with coxae and hind femora concolorous with the body, and the trochantellus, the knees, the tip of tibiae and the underside of tarsi, yellowish.

♀. Head transverse, a little less broad than the thorax. Eyes large, oval; cheeks short and rounded. Antennae inserted near the clypeus, shortly below the lowest level of the eyes; scape short, slightly enlarged, oval, about 3.5 times as long as broad; pedicel short, as long as one-third of the scape; one small annellus; the 6 joints of the funicle progressively broader and shorter, the 1st longer than broad, a little longer than the pedicel, the 4th and 5th subquadrate, the 6th slightly broader than long; club with 3 joints, almost as long as the three preceding joints together.

Thorax very finely punctate, almost smooth, shining. Pronotum as long as the mesonotum, narrowed in front, with the sides rounded; mesonotum broader than long, covered with small white ciliae; parapsidal furrows complete and deep; scutellum scarcely longer than broad, with four longer ciliae, two on each side near the margins; propodeon smooth and shining, without longitudinal carinae; mesopleurae smooth, with a short transverse furrow below the wings. Wings large, longer than the body in the proportion of 6 to 5; alar discus entirely ciliate; marginal ciliae short; marginal vein as long as the submarginal, which is broken; stigmal vein narrow and short, with a relatively long hook; post-marginal vein 3 times as long as the stigmal and about as long as three-quarters of the marginal. Legs with the hind femora slightly flattened; tarsi short, with 5 joints.

Abdomen small, not longer and sometimes narrower than the thorax, pointed at tip; petiole small, as long as broad, the following segments broad and short, subequal in length. Ovipositor scarcely protruding.

♂. Differs from the female only in the form of the antennae and the abdomen, and the tarsi with only 4 joints. Antennae narrower, with the funicle joints a little longer, the first 1.5 times as long as broad, the distal ones subquadrate; pedicel more rounded; flagellum covered with rather long white ciliae. Abdomen shorter and narrower than the thorax, the sides more or less parallel, the petiole a little longer than broad.

Length: ♀♂ 0.9–1.1 mm.

SWEDEN: Aryd, 6 ♀ 6 ♂, em. 29.vi–2.viii.1935.

Host: eggs of *Diprion sertifer*, Geoffr.

This species had already been observed in Germany and was mentioned by W. Baer (Naturwiss. Z. Forst. u. Landwirtschaft, Stuttgart, **14**, 1916, p. 307); among notes on the biology of *Diprion* spp. he says that the eggs, especially of *D. pini*, *D. sertifer* and *D. pallidus*, are at times very heavily parasitised by what is believed to be a species of the Chalcid genus *Tetracampe*, Först.

Only two species of *Tetracampe* are known in Europe, *T. impressa*, Först. (= *Entedon panyas*, Walk.) and *T. galerucae*, Fonsc. Both seem to be rare everywhere; we have only been able to examine a male of *panyas*, Walk., in the British Museum. But Thomson (Hym. Scand., **5**, 1878, p. 182) records and describes both species from Sweden, and Masi (Boll. Soc. ent. ital., **66**, 1934, p. 88) gives a short note on a male of *T. impressa* from Italy. Both these species seem to be parasites in the eggs of *Galeruca* spp.

A short key will help to distinguish the three actually known species.

1. Tibiae and tarsi of the female, the entire legs of the male, yellowish; antennae a little thickened, with the pedicel elongate. Size 2 mm.....*T. galerucae*, Fonsc.
- Tibiae and tarsi darkened in the two sexes; antennae scarcely thickened, pedicel shorter2
2. Hind tibiae black, first tarsal joint yellow; propodeon densely punctate; size 2–3 mm.....*T. impressa*, Först.
- Tip of hind tibiae yellow; tarsi brown above, yellow below; propodeon smooth and shining; size 1 mm.....*T. diprioni*, sp. nov.

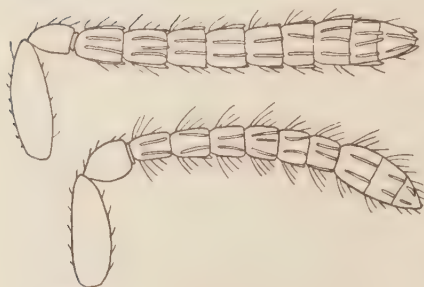


Fig. 1. *Tetracampe diprioni*, sp. n.; antennae of female (above) and of male (below).

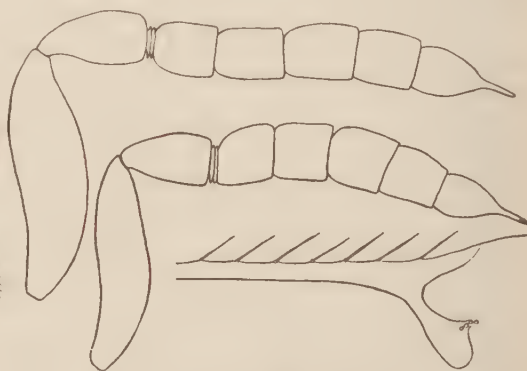


Fig. 2. *Achrysocharella ruforum*, Krausse; antennae of male (above); of female (below); stigmal and post-marginal veins.

Achrysocharella ruforum, Krausse.

Wolffiella ruforum, Krausse, Zeitsch. f. Forst. u. Jagdwesen, Berlin, **49**, 1917, pp. 26–35, 25 figs.

Krausse has described under the name of *Wolffiella ruforum*, n.g., n. sp., a parasite of the eggs of *Diprion rufus*, Kl. (= *sertifer*, G.) received from East Prussia. His description, based mainly on colour, is short, but the morphological characters are well defined by several small sketches, and the species is thus easily recognised. But as Krausse's notes have been published in a paper which is not easily found, we are giving a short redescription of the species.

♂♀. Dark bluish-green with some purple reflections, especially on vertex and occiput; abdomen aeneous in the middle; antennae black; legs black with metallic reflections, the knee and tip of tibiae, and the first three joints of middle and hind tarsi, yellow.

♀. Head transverse, finely punctate, dull. Seen from in front, the head is triangular, the cheeks narrow, converging towards the mouth. Mandibles with 3 small teeth. Antennae inserted a little above the lowest level of the eyes; scape slightly flattened, about 4 times as long as broad; pedicel a little shorter than half the length of the scape; two small annelli; the two funicle joints very slightly broader than long; club with three joints, each longer than the funicle joints, the third narrower and ending in a rather long spur. Thorax finely shagreened, shining; mesonotum broader than long, with complete parapsidal furrows; scutellum more or less rounded; propodeon very short, almost smooth, without median carina. Wings large, entirely hyaline; marginal ciliae short. Submarginal vein broken, a little shorter than the marginal vein; stigmal vein subsessile, oval; postmarginal vein shorter than the stigmal. Legs narrow, middle and hind femora slightly enlarged; the first three tarsal joints subequal in length, the fourth a little longer. Abdomen oval, short, not much longer than the thorax, shagreened or finely striate, the segments subequal in length. Ovipositor not protruding.

♂. Similar to the female; antennae a little longer, the scape larger, not much more than three times as long as broad; funicle joints slightly longer than broad, but each shorter than the pedicel. Abdomen not longer than the thorax.

Length: ♀♂, 0.9–1.2 mm.

CZECHOSLOVAKIA: Riesengebirge.

Redescribed from a series of 27 ♀♀, 10 ♂♂, 10.v.1935, and 7 ♀♀, 5 ♂♂, 3.vii.1935.

The genus *Wolffiella*, Krausse, erected for this species only, agrees exactly with the genus *Achrysocharella*, as described by Girault (Mem. Queensl. Mus., **2**, 1913, p. 171 and 178) for Australian species. A West Indian and an Oriental species have been also described in this genus, which will probably be found widely distributed when better known.

It is more difficult to distinguish *Achrysocharella*, Girault, from *Achrysocharis*, Girault, the only difference being that the first has two annelli in the antennae and the second only one annellus, a character which may be sometimes difficult to ascertain exactly. Nevertheless, in our present knowledge, it is better to leave *ruforum*, Krausse, which has two annelli, in the former genus. It is certainly closely related to the European species, *Achrysocharis formosa*, Westw., which was generally known as *Closterocerus formosus*, Westw., and had been redescribed under that name by Masi (Boll. Lab. Zool. Portici, **1**, 1907, p. 281); but that species has only one annellus, and may be further distinguished by the transverse dusky band on the forewings, by the longer funicle joints, which are as long as the pedicel, and by the more closely punctate and dull mesonotum.

THE BIOLOGY AND ECONOMIC STATUS OF THE COMMON BLACK ANT OF SOUTH INDIA—*CAMPONOTUS (TANAEMYRMEX) COMPRESSUS*, LATR.

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(PLATES XXIII & XXIV.)

Introduction.

Camponotus compressus, the common black ant (fig. 1), is one of the most abundant and best known species of ants in South India. The worker is a large jet-black ant ranging in length from 6 to 16 mm. with moderately large eyes, brownish legs and antennae and a prominent shining abdomen. These ants live in enormous communities, travelling long distances from their nests, and are active at all times of day and night. Though ordinarily of a peaceful disposition, when alarmed or disturbed they may display a tendency to be quarrelsome.

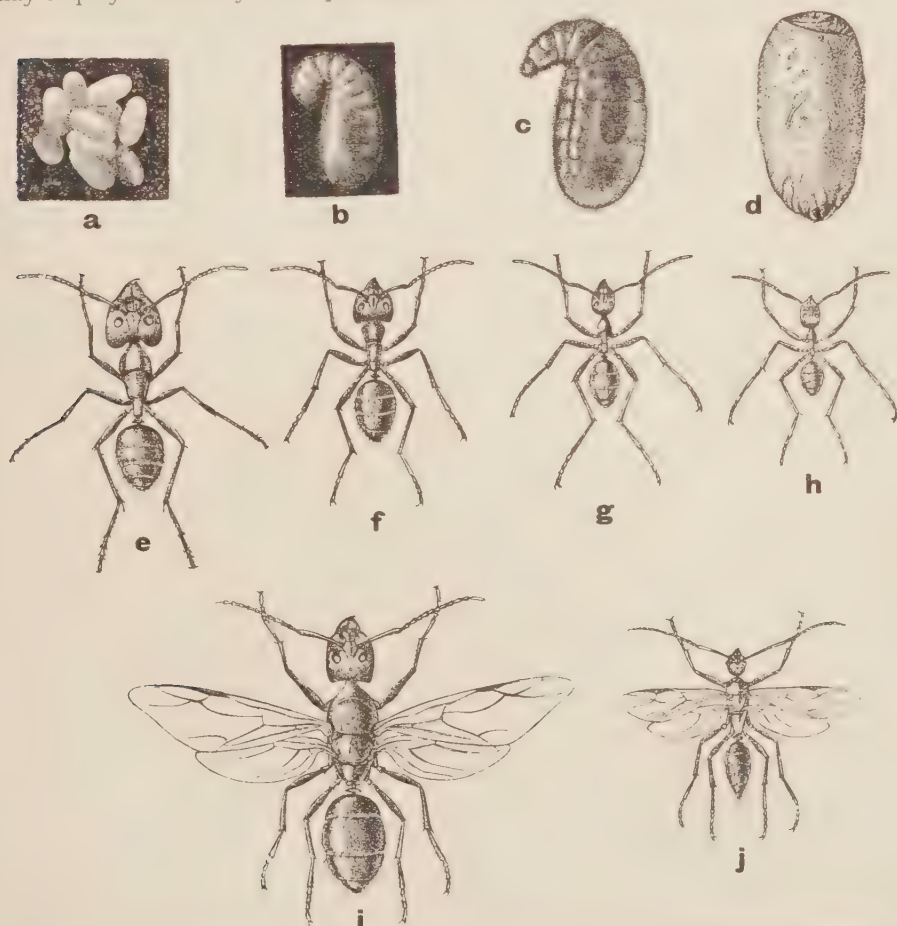


Fig. 1. *Camponotus compressus*: a, eggs; b, young larva; c, older larva; d, cocoon; e, soldier; f, worker major; g, worker media; h, worker minor; i, female; j, male.

Admirable accounts of the habits of these ants have been given by such investigators as Rothney, Wroughton and more recently Hingston, but our knowledge of these insects is still far from complete, because their study is by no means easy. Such questions as the population of the colony, their swarming season in South India, their immature stages, seasonal incidence, and above all their economic importance in relation to agriculture, have scarcely been touched upon. The present paper is an endeavour to throw some light on these problems. Towards this end, the writer has been making systematic and constant observations in the field and in artificial formicaries for some time past.

This is one of the most widely distributed species in South India and apparently manages to thrive in very varying situations, from humid to very arid regions, and ranging up to 4,500 ft. in the Shevroy Hills.

Economic Status of *Camponotus* in South India.

The agricultural importance of this insect lies in the injury it effects, in an indirect manner, on a variety of cultivated crops, ornamental plants, trees and shrubs by its symbiotic association with a host of mealybugs, scale-insects, Aphids, Fulgorids, Psyllids, Membracids and Lycaenid caterpillars. These insects draw their nutriment from the plants and produce fluid excretions which yield sustenance to myriads of *Camponotus*. The ants have developed the art of coaxing the insects with their antennae so as to make them yield drops of this sweet substance, and thus encourage further excretion, which means a greater extraction of plant sap, resulting in deeper injury to the plant. Further the ants foster and protect the pests from their natural enemies and facilitate their spread by transporting them from infested to uninfested parts. Hence the colonisation and movements of *Camponotus* have a direct bearing on the amount of injury to the plants.

So long as *Camponotus* confined itself to trees and shrubs of no great value, the resulting damage was of no consequence, but of late the ants have been observed by the writer on such economic crops as ragi, cholam, maize, cotton, red gram, lablab, citrus, zizyphus, etc., to which they often do serious injury. The nature and extent of such damage can be illustrated by some examples in ragi and a few other crops.

Ragi. (Plate XXIII, fig. 1).—In the farm attached to the college a few plants in a field of transplanted ragi began to exhibit signs of impaired growth in early July 1934. Only those plants that had a heap of loose earth at their bases in the form of a low mound were seen to be affected, and such plants at first were confined to the rows nearest to a large bund. On an examination of the plants the earth all round their roots was found to have been excavated to varying depths up to 8 or 9 inches and clusters of root aphid (*Tetraneura ulmi*) and *Camponotus* workers were seen colonising at the roots (Plate XXIII, fig. 2). The excavations had been made by the *Camponotus* to afford a good airy shelter for the Aphids and to some extent temporarily for themselves. There were no permanent nests of *Camponotus* within the field, but the adjoining bund was seen to be teeming with the ants. Day by day this infestation began to show signs of spreading, the excavations extending to rows of plants farther and farther away from the bund. By the beginning of August there were very few plants uninfested in this field and a few of the adjoining fields also showed similar symptoms. Other fields of ragi in various parts of the farm were also affected, and the infested plants began to wilt and die in some parts. The infestation was abnormal this year and the loss that followed must have been appreciable; it may be noted in this connection that the writer has been, for over fourteen years, examining such infestations systematically for demonstration to successive batches of students but has never come across such heavy and widespread damage previously. Such predators on the Aphids as Syrphid fly maggots were to be seen only occasionally in very small numbers, and the adult flies were observed

to be caught by the ants. It is evident therefore that any control measures should primarily be directed against *Camponotus*, because these are the real culprits.

Cholam and Maize. (Plate XXIV, fig. 2.)—In the case of these crops the story of the infestation and damage is the same, but the intermediary is an injurious Fulgorid, *Pundaluoya simplicia*, the Cholam shoot bug. In this crop the excavations round the plants extended even to the depth of a foot or a foot and a half. The soil in the area is a loose sandy loam and probably most suitable for *Camponotus* nests. The Fulgorid has been noted to infest shoots, but during the latter half of November and early December 1933 the crop was heavily infested with *Pundaluoya* and *Camponotus* at the roots, which had not previously been observed. Many of the attacked plants wilted and some actually died. This area has also a large bund on one side harbouring plenty of *Camponotus* nests.

Cotton.—In a large field of Karunganni cotton about five months old there was a very bad infestation of *Aphis gossypii* in association with large numbers of *Camponotus*. In this case only the above-ground portions, such as shoots and leaves, were attacked. Almost every plant so infested had a temporary shelter at the root indicated by the low mound of loose earth caused by the excavation made by the ants. In such excavations swarms of workers were lodged temporarily and these attended on the Aphids above. Small numbers of Coccinellid larvae were often noted to feed on the *Aphis*, but ladybird adults were caught and dragged away by the ants, as also not infrequently adults of *Chrysopa*. The ladybird larvae seemed to be free from the attacks of ants, probably because of their spiny bodies.

Red Gram.—In August this year a crop of red gram showed huge excavations all round their roots to a depth of very nearly a foot, made by *Camponotus*. Within these underground shelters on the roots there were numerous Membracid nymphs and adults attended by throngs of black ant workers. The damage was not inconsiderable and the story of the infestation is similar to those described above.

Lablab.—In the case of this crop the most remarkable feature is the presence of a triple or quadruple association. *Aphis medicaginis* and *Ceroplastodes cajani* were seen infesting shoots, buds and other parts in thick clusters, and caterpillars of *Catachrysops cnejus* were heavily attacking the pods, all of these insects being attended by *Camponotus*. The resulting damage by this multiple association was certainly very severe and several cases of complete failure of crops were observed.

In regard to various other cultivated crops and valuable trees the nature of the infestation is similar, except that the pests tended by the ants belong to different species of Coccids, Aphids, Psyllids, etc. It is evident from the foregoing paragraphs that *Camponotus* is mainly responsible for great havoc inflicted on various economic plants, and its claim to be regarded as a serious menace in crop production seems to be well established.

Even as a household pest the activities of this species are not altogether negligible. They invade houses in numbers and sometimes swarm on roofs and floors of houses adjoining infested trees. In the college residential quarters it has been noted that such annoyances are at their maximum during September and October.

The Formicary.

The nests of *Camponotus* are found in abundance in loose sandy loamy soil, and as Hingston rightly points out, the best site for them is at or near the base of tree-trunks, which would naturally ensure an unfailing supply of provender even in very bad seasons. But on actual excavation of several such colonies by the writer it has been observed that the nest proper, i.e. the lodgings of the queen and brood, is often placed at a distance from the base of the infested tree and is connected to the latter by numerous tortuous underground galleries. Externally, especially after the rains, the presence of a colony of *Camponotus* is indicated by the numerous

List of Insects associated with Camponotus compressus with their Host Plants in South India.

Scientific name of plant	Popular name of plant	Name of associated insects	Family	Infested part of plant	Degree of infestation
<i>Eleusine coracana</i>	Ragi	<i>Tetraneura ulmi</i>	Aphididae	Roots	Severe
<i>Andropogon sorghum</i>	Cholam	<i>Pundaluoya simplicia</i>	Fulgoridae	Roots & shoots	Severe
<i>Dolichos lablab</i>	Lablab	<i>Forda</i> sp.	Aphididae	Roots	Slight
		<i>Aphis medicaginis</i>	Aphididae	Shoots	Severe
		<i>Ceroplastodes cajani</i>	Coccidae	"	"
<i>Gossypium indicum</i>	Cotton	<i>Catachrysops cnejus</i>	Lycaenidae	Pods	Slight
		<i>Aphis gossypii</i>	Aphididae	Shoot	Severe
		<i>Saissetia nigra</i>	Coccidae	Shoot & stem	Slight
<i>Cajanus indicus</i>	Red gram	Membracids	Membracidae	Root & shoot	Severe
<i>Zea mays</i> ...	Maize	<i>Pundaluoya simplicia</i>	Fulgoridae	"	"
<i>Citrus</i> ...	—	<i>Aphis traversi</i>	Aphididae	Shoot	"
		<i>Icerya aegyptiaca</i>	Coccidae	"	Slight
<i>Sesbania grandiflora</i>	Agathi	Membracids	Membracidae	"	Severe
<i>Acacia arabica</i>	Babul	<i>Phenacoccus iceryoides</i>	Coccidae	"	"
		<i>Anomalococcus indicus</i>	Coccidae	"	"
<i>Acacia leucophloea</i>	White babul	Membracids	Membracidae	"	"
<i>Acacia auriculiformis</i>	—	<i>Anomalococcus indicus</i>	Coccidae	"	"
		Membracids	Membracidae	"	"
<i>Morinda tinctoria</i>	Morinda	<i>Pulvinaria psidii</i>	Coccidae	"	"
		<i>Lecanium viride</i>	"	"	"
<i>Erythrina indica</i>	Indian Coral tree	<i>Saissetia oleae</i>	"	"	Slight
<i>Cordia myxa</i> ...	—	<i>Diaphorina cordiae</i>	Psyllidae	"	Severe
<i>Psidium guava</i>	Guava	<i>Pulvinaria psidii</i>	Coccidae	"	Severe
		<i>Icerya aegyptiaca</i>	"	"	Slight
<i>Hibiscus rosasinensis</i>	Shoe-flower	<i>Saissetia nigra</i>	"	"	Severe
<i>Ipomoea carnia</i>	Bluebell	<i>Phenacoccus iceryoides</i>	"	"	Slight
<i>Achras sapota</i> ...	Sapota	<i>Saissetia oleae</i>	"}	"	Severe
		<i>Lecanium viride</i>			
		<i>Pulvinaria psidii</i>			
		<i>Pseudococcus longispinus</i>			
<i>Moringa pterygosperma</i>	Drumstick plant	Membracids	Membracidae	"	Slight
<i>Feronia elephantum</i>	Wood apple	Membracids	"	"	"
<i>Mangifera indica</i>	Mango	<i>Phenacoccus mangiferae</i>	Coccidae	"	"
		<i>Phenacoccus iceryoides</i>			
<i>Tamarindus indicus</i>	Tamarind	<i>Pseudococcus corymbatus</i>	"}	"	"
		<i>Pseudococcus lilacinus</i>			
		<i>Aspidiotus tamarindi</i>			
		<i>Saissetia oleae</i>			
		Membracids			
<i>Terminalia catappa</i>	Indian almond	<i>Saissetia nigra</i>	Membracidae	"	Severe
<i>Caesalpinia coriaria</i>	Divi	Membracids	Coccidae	"	Slight
<i>Delonix regia</i> ...	Gulmohr	<i>Monophlebus</i> ?	Coccidae	"	Severe
		Membracids	Membracidae	"	Slight
<i>Crataeva religiosa</i>	—	<i>Phenacoccus iceryoides</i>	Coccidae	"	Severe
		<i>Saissetia oleae</i>	"	"	Slight

List of Insects associated with *Camponotus compressus* with their Host Plants in S. India.—cont.

Scientific name of plant	Popular name of plant	Name of associated insects	Family	Infested part of plant	Degree of infestation
<i>Enterolobium saman</i>	Raintree	<i>Phenacoccus iceryoides</i>	Coccidae	Shoot	Slight
<i>Stenolobium stans</i>	Tecoma	Membracids	Membracidae	"	Severe
<i>Cassia siamea</i> ...	—	"	"	"	"
<i>Melia azadirachta</i>	Nim	<i>Pulvinaria maxima</i>	Coccidae	"	"
<i>Ailanthus excelsa</i>	—	<i>Pseudococcus lilacinus</i>	"	"	"
<i>Zizyphus jujuba</i>	—	<i>Tarucus theophrastus</i>	Lycanidae	"	"
<i>Cassia auriculata</i>	—	Jassids	Jassidae	Root	Slight
<i>Capparis</i> sp. ...	—	Aphids	Aphididae	Shoot	"
<i>Thespesia populnea</i>	—	<i>Phenacoccus iceryoides</i>	Coccidae	"	Severe
<i>Portia</i>	Portia	<i>Saissetia nigra</i>	"	"	"

conical low mounds or craters formed of loose earth and having an oval, circular or elliptical base (Plate XXIV, fig. 1). These are more or less uniform in shape and size, rarely exceeding five or six inches in height and one foot in diameter. They have generally one or two funnel-shaped openings at the summit, rarely exceeding one inch in diameter, and numerous subsidiary inconspicuous openings in the surrounding area. At the base of plants or trees the heap of loose earth takes the form of a ridge all round the trunk, with several narrow openings. Often after the October rains whole bunds and meadows in well-infested localities may be seen honey-combed with underground passages and craters.

These external openings lead into a net-work of narrow irregular galleries in all directions, which are very extensive, sometimes covering an area of 30 or 40 sq. ft. or more and reaching an average depth of 3 ft., but descending to 5 ft. during December to April so as to secure sufficient humidity for the brood. The underground passages, varying in diameter from $\frac{1}{2}$ to $\frac{3}{4}$ inch, expand irregularly into small semi-circular or elliptical chambers with vaulted ceilings and flat floors to afford shelter for the brood of assorted groups, as also for the assemblage of workers. These chambers seldom exceed 3 or 4 inches in length and $\frac{3}{4}$ inch in height and may be located from 3 inches from the surface to varying depths according to the season. Many scores of these nests have been dug up and examined by the writer in the course of the past year or more, and the description of one such nest will probably give a good idea of the general construction.

A nest excavated in the month of August had about 17 such chambers or expansions extending to a depth of $2\frac{1}{2}$ ft. and connected by irregular galleries. The uppermost chambers, numbering about 11 at depths of 2 in. to $1\frac{1}{2}$ ft. from the surface, were filled with cleaned cocoons. Two chambers perhaps a little lower down were filled with dirty cocoons, larvae and loose soil; three others still lower down were crowded with larvae of different sizes; and the lowest chamber was occupied by three dealated queens, with a large number of eggs, larvae and workers. The workers were ubiquitous and swarmed in the chambers and passages. Empty cocoons, refuse food and remains of dead ants of their own species were found packed in two other hollows, one of which was near the surface and the other deeper down. There were no winged queens or males; although from mass collections of pupae occasionally one or two males were seen to emerge.

Several experiments with the mixing of colonies of the same species have yielded perplexing results. In some cases the two colonies seemed to live amicably together, but in others the introduced ants were found dead in a day or two. Probably in the former case the ants were derived from the same stock and more closely related to each other than in the latter case.

The entrance to the nest is guarded by a large array of soldiers, and these, as well as the large workers, are capable of inflicting a very painful bite, even drawing blood. To add to the pain they also bend the gaster so as to bring its tip to the wound and introduce a little formic acid.

The Swarming Season and Proportion of Sexes.

The swarming season may vary slightly in accordance with the meteorological conditions, but it ordinarily ranges from April to July; occasionally stray winged forms have been collected at other times also. The males begin to swarm soon after the April showers and continue to appear till the middle of June. The females are seldom found in numbers in April but appear much later and usually swarm from the second week of May to the middle of June. A small emergence of the two sexes also occurs after the rains in October. The marriage flight takes place in the evenings between 6.30 and 9 p.m., as the winged sexual forms are crepuscular. The males far outnumber the females, and from a few quantitative collections made during the season it may be roughly calculated that females form only 10 per cent. of the swarms.

The males are normally short-lived, often dying a day or two after emergence. The longest period noted has not exceeded twenty days in artificial nests in the laboratory. Very many experiments were carried out to test the length of life of the worker and it may be concluded that they can live under normal conditions, with a queen in the colony and abundant food, for more than four months. As for the longevity of the queens, it has not been possible to ascertain this by experiment; but that they can live for several months even without food has been observed in the laboratory. Hence it is estimated that their life may, barring accidents, extend to a few years at least.

As many as 11 queens have been collected from one nest in adjacent chambers within a radius of $2\frac{1}{2}$ ft., but the number usually varies from three to seven.

Life-History.

Oviposition.

The method of egg-laying has been observed several times by isolating queens in tubes without workers and also in artificial glass nests. When attended by workers the eggs are eagerly picked up and heaped in a pile, but the queen never pays any attention to them. The eggs have a slight coating of a sticky material, so that they often adhere together, enabling the workers to transport them in heaps between their mandibles. Eggs in tubes that are not cared for by workers often become mouldy and never hatch.

The rate of oviposition has been observed to vary within very wide limits, and sometimes it is suspended for days or weeks. Two queens kept under observation laid 339 eggs in three days; but in the great majority of observed cases the number laid per diem varied from 27 to 34 eggs, averaging about 31 a day. The ovaries of a queen were dissected and were found to contain 4,808 eggs.

Several experiments with isolated groups of workers were made for two, three and four months together in order to see if they were capable of laying eggs, but the writer has observed only on one occasion a few eggs laid in a cage with workers alone. These workers all emerged from cocoons collected from outdoor nests on

30.viii.1934, and on 17.ix.1934 fourteen eggs were found to have been laid. No queens have been bred from eggs or larvae in artificial formicaries.

As stated before, eggs not cared for by workers never hatch. The minimum period taken for hatching in the month of August varies from 4 to 9 days, averaging 6 days in artificial cages.

The newly hatched worker larva (fig. 2, a, b).

The larva is vermiform and has the narrow cephalic end bent over the broader abdomen, which is more or less smooth and has the segmentation indistinct posteriorly. The head and thorax have a sparse covering of scattered hairs which are long and hooked (fig. 2, b). In later instars the hairs are distributed all over the body in thick clusters placed on slight tubercular elevations and numbers of larvae adhere together in groups by these hairs.

After the fourth day some larvae develop more rapidly in bulk than others, and it is a common sight to see larvae of differing sizes in heaps hatched from the same batch of eggs and on the same day.

The full-grown worker larva (fig. 1, c).

The body of the full-grown larva is covered with short stiff hairs (fig. 2, d, e) most of which bear 2, 3, 4, or 5 branches; of these 3- and 4-branched hairs are the most numerous.

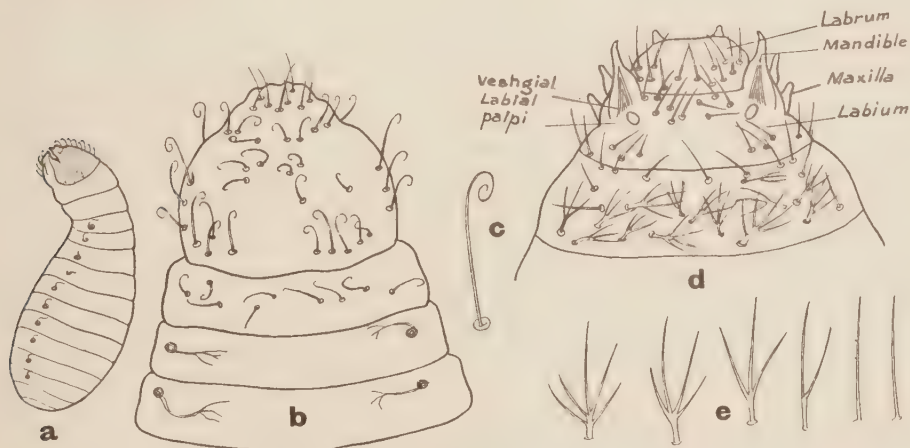


Fig. 2. *C. compressus*: a, newly hatched larva ($\times 20$); b, head and thorax of newly hatched larva ($\times 100$); c, hair on newly hatched larva ($\times 300$); d, head of full-grown larva ($\times 100$); e, hairs on full-grown larva.

The mouth-parts, though distinct, are more or less rudimentary. The mandibles are comparatively well-defined and chitinised, and sharp but not dentate. A large projection is found at the basal portion of each mandible, and the maxillae bear a fleshy process.

With the exception of slight expansions of the body and frequent straightening of the curved cephalic end the larvae are incapable of any kind of locomotion and are therefore helpless. They have to depend entirely upon the ministrations of the attendant nurses, who feed them with regurgitated liquid food, lick and groom them frequently, transport them to suitable situations, and arrange them in graded groups. At any sign of danger the larvae and eggs are carried between their mandibles and rushed to a place of safety. The nurses attend solely to these duties at home and seldom go out foraging, obtaining their supply of food from foraging workers.

The details of the process of feeding have been observed several times with the help of a lens in artificial cages. The larvae usually lie on their sides or at times on their backs. The nurses constantly inspect them, and when one comes across a hungry larva she opens her mandibles wide and brings her mouth-parts into close contact with those of the larva then ejecting a minute drop of fluid into its mouth.

The writer has not been able to identify the larval stages of queens and males.

A Census of the Community.

It is not an easy task to ascertain the exact population of a colony of *Camponotus* for various reasons. The colonies are extraordinarily populous, and a large percentage is always out of the nest on foraging expeditions. Thus it is almost impossible to arrive at an exact calculation, particularly in the most flourishing colonies. Yet some attempts were made to compute the numbers of a few small colonies. One disproportionately small colony located far away from trees on a bund was dug out and the whole lot of soil with the occupants was carried into the laboratory in huge glass jars. These were chloroformed and the population sorted, and the census gave the following figures:—79 eggs, 409 assorted larvae, 311 cocoons of four sizes, 46 soldiers, 671 workers, and 3 dealated queens.

This census may serve to give an idea of the proportion of eggs, larvae, pupae and queens in a community at that season, but would be quite misleading in regard to the worker population of a normal colony. Therefore a census of another colony, located at the foot of a small *Morinda* tree, was taken by a different method in the month of August. A particularly small tree infested with *Lecanium viride* and *Pulvinaria psidii* was selected, as the foragers would be too widely distributed on the branches and leaves of a larger tree. An application of a sufficient quantity of potassium cyanide solution (1 oz. to 1 gal. of water) was made at about 11 a.m. all round the tree until the whole area was soaked with it. This time was chosen because on a hot day the streams of workers ascending the tree would then be at their minimum. On examination after 2 hours a large heap of dead ants and a few smaller heaps of dead and dying specimens were found at the foot of the tree. The number of workers and their weight were recorded. There were 6,739 workers, with a total weight of 35.2 grams. Even this figure does not represent the actual population of the colony, as there were still several hundreds on the leaves of the small tree (averaging about 4 to 6 to a leaf), and others might be foraging elsewhere. Therefore it might be assumed that the population would probably not be less than 10,000. It may be noted that this was one of the smallest colonies located at the foot of a tree.

Seasonal Incidence and Relative Abundance.

The following observations are based on systematic excavations of natural formicaries in different situations for a period of over 12 months, averaging about four times a month. Several scores of nests must have been handled during the period, so as to obtain reliable data on the changes occurring in these communities due to seasonal vicissitudes. Commencing from April, soon after the seasonal showers, the temperature goes down somewhat and the food available tends to increase, so that the colonies show signs of the beginning of activity and small numbers of workers may at times be observed in the vicinity. In the nests themselves a few immature stages can be collected. About this time large swarms of winged males emerge. By the beginning of the next month, after a few more showers, the emergence of females commences along with that of males and reaches its peak by the middle of the month. Meanwhile the food supply is on the increase. Trees and shrubs begin to harbour crowds of scale-insects, mealybugs, Aphids, etc. The appearance of sexual forms is naturally followed by the marriage flight, and in July the immature stages, particularly worker larvae, steadily rise in numbers.

From July till the middle of August the population steadily grows, especially the immature stages. From August till the end of September the nests contain more cocoons and teneral adults than larvae and the depth of the galleries is at its minimum. From this period till the middle of November the colonies are most populous and flourishing. The nests are excessively crowded and soon after the north-east monsoon showers in early October, the whole of the infested locality may be seen studded with fresh mounds and myriads of new temporary branch nests are started. A slight emergence of winged sexual forms in very nearly equal proportions occurs soon after the showers. Trees, shrubs, open grounds and roads and even dwelling houses may be seen teeming with the indefatigable foragers. Towards the end of November there is a gradual slackening of activities, and from December the colonies appear to be deserted or dormant, and the nests and mounds are levelled up and closed. Until about March activities are at a minimum and the population is at its lowest. The nests are now at their deepest, the tunnels attaining a depth of 4 ft. or more, and in their inner recesses groups of replete workers can be observed. Large accumulations of remains of dead ants may be seen inside in the vicinity of their galleries. Excavations by workers on the surface are seldom observed except during February after some slight showers.

Food Habits.

As already mentioned, their most favoured food is the sweet excretion of Homoptera and Lycaenids, but they also abstract vegetable juices from tender shoots, flowers or the sacchariferous glands at the bases of the leaves of certain plants. Workers can often be seen carrying bodies of soft-bodied insects on their return from foraging expeditions, such as moths, Syrphid flies, Melolonthid grubs, termites, honey-bees, grasshopper nymphs, small weevils and other beetles, caterpillars (excluding hairy ones) and other species of ants, particularly *Solenopsis*. They are also cannibalistic and often feed on eggs, larvae and pupae of their own species.

But no food of any kind is kept in storage in their nests, and all remains are disposed of immediately after feeding. The liquid food that is continually brought in by foragers is kept sometimes in reserve in the capacious crops of replete workers to tide over periods of food scarcity, and this is shared and consumed as soon as exigencies require. Streams of workers returning to the nest with swollen abdomens are often met by their hungry sisters with the usual antennal greetings and exchange of food by regurgitation takes place.

The cleanliness of these ants is remarkable. Their bodies and antennae are constantly cleaned by the tarsi, and these latter are cleaned in turn by being pulled between the maxillae. Eggs, larvae, pupae, and queens are continually groomed by workers, and the same operation is carried on among themselves. The chambers and galleries are also freed of all remains of food, nor do they tolerate other animals in or near their habitations. The only exceptions are certain spiders and woodlice (ONISCIDAE), which remain with impunity in close proximity. The spiders (recently described by Dr. Gravely as *Annandaliella pectinifera*) often run into the galleries and are probably myrmecophilous.

Camponotus, which ordinarily infests a considerable variety of plants, seems to avoid a few poisonous plants, even though these may be situated in the vicinity of its nest. Among such plants are the following : *Jatropha curcas*, *Datura fastuosa*, *Plumeria acutifolia*, *Calotropis gigantea*, and *Thevetia nerifolia*.

Even when such plants harbour sap-sucking Homoptera these ants do not seem to care to live in association with them. *Calotropis* and *Thevetia* may occasionally have a few vagrant *Camponotus*, but the others are noted to be completely free.

Control.

Natural factors.—This species seems to be particularly free from such enemies as parasites. On the other hand, a few predators have been noted, particularly spiders, and there are also a few birds that occasionally feed on these ants. Among these the common crow (*Corvus splendens*) has been often noted to perch on infested trees and pick up the ants. The sexual winged forms have probably many more enemies.

Even heavy rains seem to have little effect on their control unless there be continuous flooding of the area for many days together, when the colony may migrate as a whole to some more suitable spot. Heavy rains often effect some slight damage to their subterranean chambers and may destroy a large number of foraging and wandering workers. These ants are not, however, generally afraid of water and have been observed to cross (by wading or by clumsily swimming) small sheets of stagnant or running water. Experimental flooding of colonies at the foot of trees, by diverting water channels temporarily, has been tried, and swarms of workers have been seen hurrying up the trees or plants and forming packed masses on them until the floods subside, when with redoubled vigour they begin to repair their nests.

Owing to the fact that a heavily infested area is often honeycombed with nests having extensive and intricate galleries, any methods of control should be on a very extensive scale in order to produce any tangible relief. It may also be noted that any measures taken to kill the workers or foragers alone, which form a large contingent of the population, may be futile, as the perennial source of production, the nests, may make good such loss within a short time. It is as well to note that no extensive trials in their control have been carried out for want of adequate facilities. A few experiments on a limited scale, however, have been made in order to gauge their possibilities.

Crude oil emulsion.—A few trials with this substance mixed with irrigation water in an infested ragi plot effected no appreciable relief, nor was any permanent decrease in infestation observed by the application of this emulsion round the roots of infested individual plants, except some temporary reduction in numbers for a day or two.

Fumigation.—An application of calcium cyanide dust into the nests or other temporary shelters was useful in reducing the worker population. But the gas evolved does not penetrate into the innermost recesses, even if pumped in, and hence fails to affect the queen and brood which are at depths of $2\frac{1}{2}$ to $4\frac{1}{2}$ ft.

Carbon bisulphide.—A few nests on the bunds and round trees were treated with carbon bisulphide. This was poured on cotton wool and placed inside exit holes and passages lower down. The gas being heavier than air penetrates into the galleries to a great extent, and such nests when dug up showed large swarms of workers killed. But the most serious drawback to this method is that large crowds of workers march out through numerous minute openings all round and at varying distances from the nests and thus evade the effect of the fumes. Yet a small measure of success is possible by constant and repeated trials in one locality. Arsenical fumes injected with an ant exterminator machine might perhaps have been more fruitful in such cases.

Potassium cyanide.—Experiments with a solution of potassium cyanide in the proportion of 1 oz. to 1 gal. of water proved more successful when the situations of colonies could be exactly located. In making these experiments a small portion of a long bund bordering a ragi field heavily infested with ants and root aphid was selected. Almost every plant in the field had its roots crowded with clusters of Aphids and worker ants, but it was evident from the gradual spread of the infestation that the permanent colonies of ants were in the bunds, and hence the treatment was directed to the bunds mainly. The time selected was mid-day when the foragers that had gone out were at their minimum. The entire area, including the sides of

the bund for a distance of 3 ft., was thoroughly soaked with the solution, and large quantities were also actually poured into the openings of the nests. The workers in the passages near the surface were killed within a few minutes, and others trying to escape the gas through openings were also killed within a very short time. On examination of the colony the next day the passages were filled with heaps of dead ants and many of the immature stages were also found to be dead. Those ants that returned to the nest after foraging expeditions were seen dead on the surface in heaps. But it was not possible to gauge the effect of the treatment on the adjoining ragi plants as the treated portion of the bund formed only a small area when compared with the rest, which harboured a large number of colonies that continuously supplied enough workers to replace the dead.

It was in the case of colonies round the bases of tree-trunks that this treatment was seen to be most effective. A small *Morinda* tree badly infested by ants, *Pulvinaria psidii* and *Lecanium viride*, was chosen for trial. Two applications of the solution of potassium cyanide with an interval of two days were enough to reduce the population of ants to a few hundreds. The queens and the younger stages were also killed. A few more applications would have very nearly wiped out the infestation altogether. It may, therefore, be safe to conclude from these experiments that the possibilities of this method of control are certainly greater than others that were given a fair trial.

Acknowledgments.

The writer wishes to place on record his indebtedness to Dr. T. V. Ramakrishna Ayyar for the identification of the Coccid associates of *Camponotus* and for allowing access to the collections in his charge. His thanks are due to Dr. W. M. Wheeler of Harvard University, who kindly confirmed the identification of the ant, and to Dr. Gravely of the Madras Museum for identifying a few spiders. The writer is also grateful to the successive Principals of this college, Mr. R. C. Broadfoot and Rao Bahadur D. Ananda Rao Garu for affording facilities for work on this problem.

EXPLANATION OF PLATES XXIII AND XXIV.

PLATE XXIII.

- Fig. 1. Ragi plants showing severe infestation of *C. compressus* and root aphid (*Tetraneura ulmi*).
„ 2. Ragi roots with *C. compressus* workers attending clusters of nymph and adult root aphid.

PLATE XXIV.

- Fig. 1. Large nest of *C. compressus* showing the entrance.
„ 2. Cholan (*Sorghum*) plants badly infested and showing large nests of *C. compressus* at roots attending on *Pundaluoya simplicia* (Fulgoridae) (Cholan shoot bug attacking roots).



Fig. 1.



Fig. 2.

Joindae-vira & *L. angustata* (Hb.) Inden



Fig. 1.



Fig. 2.

NESTS OF CAMPONOTUS COMPRESSUS.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st July and 30th September, 1935:—

Mr. H. M. ALLEYNE :—4 Lepidoptera, 13 Orthoptera, and 9 egg masses ; from Tanganyika Territory.

Mr. E. BALLARD, Government Entomologist :—61 Diptera, 117 Coleoptera, 28 Parasitic Hymenoptera, 4 other Hymenoptera, 55 Lepidoptera, 13 Rhynchota, 10 Orthoptera, 2 Planipennia, and 2 Odonata ; from Palestine.

Dr. H. F. BARNES, Rothamsted Experimental Station :—5 Parasitic Hymenoptera ; from England.

Dr. C. F. C. BEESON, Forest Zoologist :—29 Curculionidae ; from the United Provinces, India.

Mr. C. A. BLÉTON :—8 Coleoptera ; from Morocco.

Mr. P. BORG, Plant Pathologist :—1 species of Coccidae ; from Malta.

Mr. H. J. BRÉDO :—13 Lepidoptera and 5 early stages ; from the Belgian Congo.

Mr. A. E. BROOKES :—77 Curculionidae ; from New Zealand.

Mr. I. BULL :—5 species of Coccidae ; from South Coorg, India.

BURMA-SIAM RICE COMPANY :—8 Coleoptera ; from Siam.

Prof. P. A. BUXTON, London School of Tropical Medicine :—29 Tabanidae, 49 *Simulium*, 72 other Diptera, 8 Hymenoptera, 17 Planipennia, and 5 Trichoptera ; from Europe.

CHIEF ENTOMOLOGIST, PRETORIA :—2 Lepidoptera ; from South Africa.

Mr. J. T. CHU :—24 Parasitic Hymenoptera and 32 Lepidoptera ; from China.

COLONIAL SECRETARY, GIBRALTAR :—1 Cerambycid ; from Gibraltar.

Mr. G. H. CORBETT, Government Entomologist :—10 Diptera, 84 Coleoptera, 83 Parasitic Hymenoptera, 24 Formicidae, 39 Lepidoptera, 22 Rhynchota, and 5 Orthoptera ; from Malaya.

Mr. G. S. COTTERELL, Government Entomologist :—8 *Glossina*, 6 Coleoptera, 28 Parasitic Hymenoptera, 6 Lepidoptera, 14 Thysanoptera, 5 species of Coccidae, 1 species of Aleurodidae, 13 other Rhynchota, and 4 Chelifera ; from the Gold Coast.

Mr. A. CUTHBERTSON, Assistant Entomologist :—6 Psychodidae and 30 other Diptera ; from Southern Rhodesia.

Mrs. H. R. P. DICKSON :—19 Orthoptera ; from Arabia.

Miss Z. DICKSON :—33 Orthoptera ; from Arabia.

DIRECTOR OF PUBLIC WORKS, LAGOS :—6 Formicidae ; from Nigeria.

DIRECTOR OF TSETSE RESEARCH :—164 Orthoptera ; from Tanganyika Territory.

Mr. A. P. DODD :—36 Curculionidae ; from Queensland.

Mr. V. H. W. DOWSON :—14 Coleoptera and 10 larvae and 100 Mites ; from Iraq.

EMPIRE COTTON GROWING CORPORATION :—2 Coleopterous early stages, 7 Parasitic Hymenoptera and 4 cocoons ; from South Africa.

Mr. A. E. EVANS :—5 Diptera ; from England.

Mr. R. L. E. FORD :—23 Braconidae ; from England.

Dr. A. B. GAHAN :—22 Parasitic Hymenoptera ; from the United States of America.

Mr. S. GARTHSIDE :—2 Diptera, 31 Coleoptera, 26 Parasitic Hymenoptera and 25 cocoons, 7 Rhynchota, and 5 Planipennia ; from England.

Mr. J. GHESQUIÈRE :—265 Coleoptera and 100 Parasitic Hymenoptera ; from the Belgian Congo.

Mr. C. C. GHOSH :—21 Coleoptera ; from Burma.

Mr. F. D. GOLDING, Government Entomologist :—13 *Glossina*, 7 other Diptera, 11 Coleoptera, 4 Hymenoptera, 10 Lepidoptera, 15 species of Aleurodidae, 10 other Rhynchota, and 2 Orthoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—24 Diptera and 9 puparia, 50 Coleoptera, 38 Parasitic Hymenoptera and 2 cocoons, 14 other Hymenoptera, 5 Lepidoptera, and 6 Rhynchota ; from South India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—4 Diptera and 3 pupa cases, 44 Coleoptera, and 12 Parasitic Hymenoptera ; from the Punjab, India.

Mr. G. L. R. HANCOCK :—24 Diptera, 280 Coleoptera, 9 Parasitic Hymenoptera, 169 Rhynchota, 100 Psocidae, and 15 Spiders ; from Mt. Kenya.

Mr. E. HARGREAVES, Government Entomologist :—2 Culicidae, 16 other Diptera, 25 Coleoptera, 9 Parasitic Hymenoptera, 5 other Hymenoptera, 69 Lepidoptera, and 3 Rhynchota ; from Sierra Leone.

Mr. W. V. HARRIS, Assistant Entomologist :—60 Lepidoptera and 20 early stages, and 5 Rhynchota ; from Tanganyika Territory.

Mr. K. J. HAYWARD :—5 Diptera, 6 Lepidoptera and 2 early stages ; from the Argentine.

Mr. H. J. HOCKINGS :—46 Lepidoptera ; from Queensland.

IMPERIAL ENTOMOLOGIST, PUSA :—8 Coleoptera ; from India.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—86 Coleoptera, 60 Lepidoptera, 70 Thysanoptera, 2 species of Coccidae, 33 other Rhynchota, 3 Orthoptera, and 200 Mites ; from the Dutch East Indies.

Miss D. J. JACKSON :—81 Parasitic Hymenoptera and 117 cocoons ; from Scotland.

Mr. S. G. JARY :—150 Parasitic Hymenoptera ; from England.

Mr. W. F. JEPSON :—156 Diptera and 27 Hymenoptera ; from Mauritius, Java, and Madagascar.

Mr. C. B. R. KING :—12 Diptera and 3 puparia, and 16 Parasitic Hymenoptera ; from Ceylon.

Mr. H. KUTTER :—3 Parasitic Hymenoptera ; from Switzerland.

Mr. G. C. LAWRENCE :—4 Hymenoptera ; from England.

Mr. R. A. LEVER, Government Entomologist :—10 Culicidae, 2 *Tabanus*, 217 other Diptera, 214 Coleoptera, 72 Parasitic Hymenoptera, 102 other Hymenoptera, 104 Lepidoptera, 3 species of Coccidae, 162 other Rhynchota, 13 Orthoptera, 2 Embiididae, 8 Odonata, 80 Mallophaga, 50 Mites, 20 Spiders, 2 Millipedes, 3 Parasitic Worms, 8 Crustacea, and 43 Shells ; from the Solomon Islands.

Miss K. O. V. LIEU :—4 Lepidoptera ; from China.

Mrs. K. C. MACKAY :—1 Telephorid and 1 Vespidae ; from Ireland.

Dr. R. MAYNÉ :—3 Diptera, 25 Coleoptera, 10 Formicidae, 4 slides of Coccidae, 4 other Rhynchota, and 6 Collembola ; from Colombia.

Dr. D. MILLER, Cawthron Institute :—168 Parasitic Hymenoptera ; from New Zealand.

- Mr. S. MORRIS :—14 Parasitic Hymenoptera ; from England.
- Mr. J. MUGGERIDGE, Government Entomologist :—3 Coleoptera, 2 Thysanoptera, and 1 species of Nematode ; from New Zealand.
- Mr. A. PAILLOT :—6 Parasitic Hymenoptera ; from France.
- Mr. E. F. PECK, Veterinary and Agricultural Officer :—2 Coleoptera and 123 Orthoptera ; from British Somaliland.
- Mr. H. M. PENDLEBURY, Selangor Museum :—139 Coleoptera ; from Malaya.
- Dr. H. PRIESNER :—27 Parasitic Hymenoptera ; from Egypt.
- Mr. Y. R. RAO :—13 Diptera and 5 puparia, 20 Coleoptera, 6 Parasitic Hymenoptera, 49 other Hymenoptera, 30 Lepidoptera, 6 Rhynchota, 4 Orthoptera, and 2 Chrysopidae ; from Baluchistan.
- Mr. S. A. RAU :—7 Parasitic Hymenoptera, 50 Thysanoptera, 1 species of Coccidae, 1 species of Aphidae, and 2 other Rhynchota ; from Nilgiris, India.
- Mr. O. W. RICHARDS :—36 Parasitic Hymenoptera and 29 cocoons ; from England.
- Mr. A. H. RITCHIE, Government Entomologist :—3 Diptera and 3 pupa cases, 17 Coleoptera, 71 Parasitic Hymenoptera and 8 cocoons, 90 Formicidae, 21 Lepidoptera, and 3 tubes of Fungus-infested insects ; from Tanganyika Territory.
- Mr. I. C. ROSS :—12 Siphonaptera ; from Australia.
- Mr. CH. RUNGS :—7 Parasitic Hymenoptera ; from Morocco.
- Dr. SCHWERTFEGER :—171 Parasitic Hymenoptera and 100 cocoons ; from Germany.
- Mr. H. W. SIMMONDS, Government Entomologist :—2 Diptera and 1 species of Coccidae ; from the Fiji Islands.
- Mr. C. SMEE :—7 Coleoptera, 2 Lepidoptera, 16 Rhynchota, and 76 Orthoptera ; from Nyasaland.
- Miss A. H. STEEL :—1 Tettigoniid ; from England.
- Mr. T. V. SUBRAMANIAM :—40 Diptera ; from Mysore, India.
- Mr. C. B. SYMES, Medical Entomologist :—4 Tabanidae, 730 other Diptera, 12 Coleoptera, 28 Hymenoptera, 24 Lepidoptera, 58 Rhynchota, 2 Orthoptera, 8 Ephemeridae, and 3 Spiders ; from Kenya Colony.
- Mr. E. L. TAYLOR :—150 Mites ; from England.
- Mr. G. C. VARLEY :—40 Parasitic Hymenoptera and 6 cocoons ; from England.
- Mr. R. VEITCH, Chief Entomologist :—2 species of Coccidae ; from Queensland, Australia.
- Mr. G. B. VIADO :—33 Orthoptera ; from the Philippine Islands.
- WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—9 Culicidae ; from the Sudan.
- Miss E. E. WHITWER :—100 Lymantriid eggs, 9 Flatid nymphs, and 2 tubes of Galls ; from Burma.
- Mr. F. WILSON :—6 Coleoptera, 3 Parasitic Hymenoptera, 11 Lepidoptera, 2 slides of Coccidae, 3 slides of Aphidae, and 17 other Rhynchota ; from France.
- Mr. K. YASUMATSU :—8 Parasitic Hymenoptera ; from Japan.
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